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National Aeronautics and Space Administration
Office of Advanced Concepts and Technology
Commercial Development and Technology Transfer Division

by James J. Haggerty

NASA

FOREWORD

The wealth of technology that comes from the exploration of air and space is a valuable national resource and an investment in our future. The new products and processes that arise from our work at the cutting edge of science and engineering contribute to the U.S. economy and to the nation's ability to remain competitive in the global marketplace.

While the rigors of the balance sheet are important, there is a larger perspective. Fundamentally, the work we do in harnessing new technologies can be used to enrich the lives of our citizens and the people of the world. It is added value to society that inspires our missions and motivates our people.

At NASA, we understand that in its dormant state, technology has only a potential benefit to people, like oil in the ground. Once removed from the laboratory workbench or the fileroom shelf and put to practical use, technology's real value comes alive. That is when it really begins to work for our people and our country.

In 35 years of exploring the frontiers of air and space, NASA has excelled in promoting technology transfer. In many cases, the transfer has been the product of serendipity. We can do better. We have, therefore, begun a series of initiatives to improve our technology transfer efforts. One important step was the establishment of the Office of Advanced Concepts and Technology (OACT) which serves as a focal point for technology innovation and transfer.

OACT bridges the gap between the development of technology and its application. It provides an open door to industrial, academic, and a variety of other organizations seeking to tap into the high technology network.

I have also issued a policy directive that emphasizes technology transfer as one of the fundamental missions of NASA. It calls for planning technology transfer from the very beginning of our major space and aeronautical programs.

In the months ahead, we intend to stimulate and accelerate the creation of new small businesses based on technology innovations. We will improve our partnerships with state and local governments, create new government and industry partnerships where appropriate, and develop outreach programs to strengthen nationwide coordination of technology advancement.

I am confident that these and other initiatives will significantly enhance the technology transfer process and enable NASA to expand its already impressive contribution to the nation's economy and competitiveness.

Daniel S. Goldin
Administrator
National Aeronautics and Space Administration

INTRODUCTION

In his February 1993 technology policy statement, President Clinton stated "Technology is the engine of economic growth." Technological innovation is the key element in reinvigorating American competitiveness in the global marketplace, one of the major national goals enunciated by the President.

NASA's storehouse of technology plays an important role in this renewal of America's technological base. Because it is transferrable and can be reused again and again, this technology represents a valuable national resource; it can be — and is being — applied in development of new products and processes for the world market.

NASA's space and aeronautics programs are the source for technology reapplications, or spinoffs, because they are extraordinarily demanding of technological advance and because the innovations they generate are exceptionally diverse. The technology bank has been well used by American industry. Tens of thousands of secondary applications have emerged, to the benefit of the U.S. economy, job creation, industrial productivity and the nation's lifestyle.

By Congressional mandate, NASA is responsible for promoting further expansion of spinoff in the public interest. Through its Technology Transfer Program, NASA seeks to encourage greater use of the technology bank by providing a link between the technology and those who might be able to put it to advantageous secondary use. The program's goal is to broaden and accelerate the spinoff process and to realize increased benefit from the national investment in aerospace research.

This publication is an instrument of that intent. Organized in three sections, *Spinoff 1993* is designed to heighten awareness of the technology available for transfer and its potential for public benefit.

Section 1 summarizes NASA's space and aeronautics programs, whose challenging objectives require advances across a broad scientific/technological spectrum, continually expanding the bank of technology that may find future application.

Section 2, the focal point of this volume, contains a representative sampling of spinoffs that have resulted from the secondary application of NASA technology.

Section 3 describes the various mechanisms NASA employs to stimulate technology transfer. It lists, in an appendix, contact sources for further information about the Technology Transfer Program.

The technology transfer program is ready to meet the challenge of enhancing NASA contributions to U.S. competitiveness. This effort is forging closer ties between industry, academia and government. In the coming year, NASA will continue to create more opportunities for innovation and investment to flourish to the benefit of the U.S. economy.

Gregory M. Reck

Gregory M. Reck
Acting Associate Administrator for
Advanced Concepts and Technology

SPINOFF

FOREWORD

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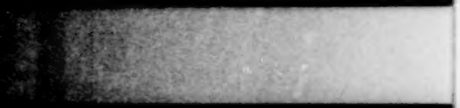
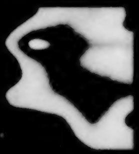
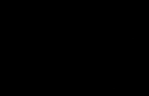
AEROSPACE AIMS



An illustrated summary of NASA's major aeronautical and space programs: their goals and directions; their contributions to American scientific and technological growth; and their potential for practical benefit





TOWARD FUTURE FLIGHT

In 1992, U.S. manufacturers produced civil aircraft valued at almost $30 billion and more than three-quarters of the total value represented sales to foreign customers. That provided a very large contribution to the U.S. Gross National Product and to the record-level aerospace international trade balance, underlining the vital importance to the nation's economy of high value civil aircraft sales.

But despite that impressive performance, the U.S. civil aircraft manufacturing industry continues to lose market share. In 1969, the United States dominated the world market for airline transport aircraft with 91 percent of all sales. By 1992, the U.S. share was down to 67 percent and falling. For two decades, U.S. plane builders have experienced intense competition from the European Airbus consortium and now new competitors — such as Russia, Japan and Taiwan — are eyeing the great economic benefits of the jetliner market.

NASA EMBARKS ON AN EXPANDED AND ACCELERATED AERONAUTICAL RESEARCH PROGRAM INTENDED TO CONTRIBUTE TO IMPROVED AMERICAN COMPETITIVENESS IN THE GLOBAL AVIATION MARKET

It is clearly time to halt the U.S. competitive slide and effect a turnaround to capture a greater share of the global market, which is estimated at $800 billion to $1 trillion for the period 1993 through 2015.

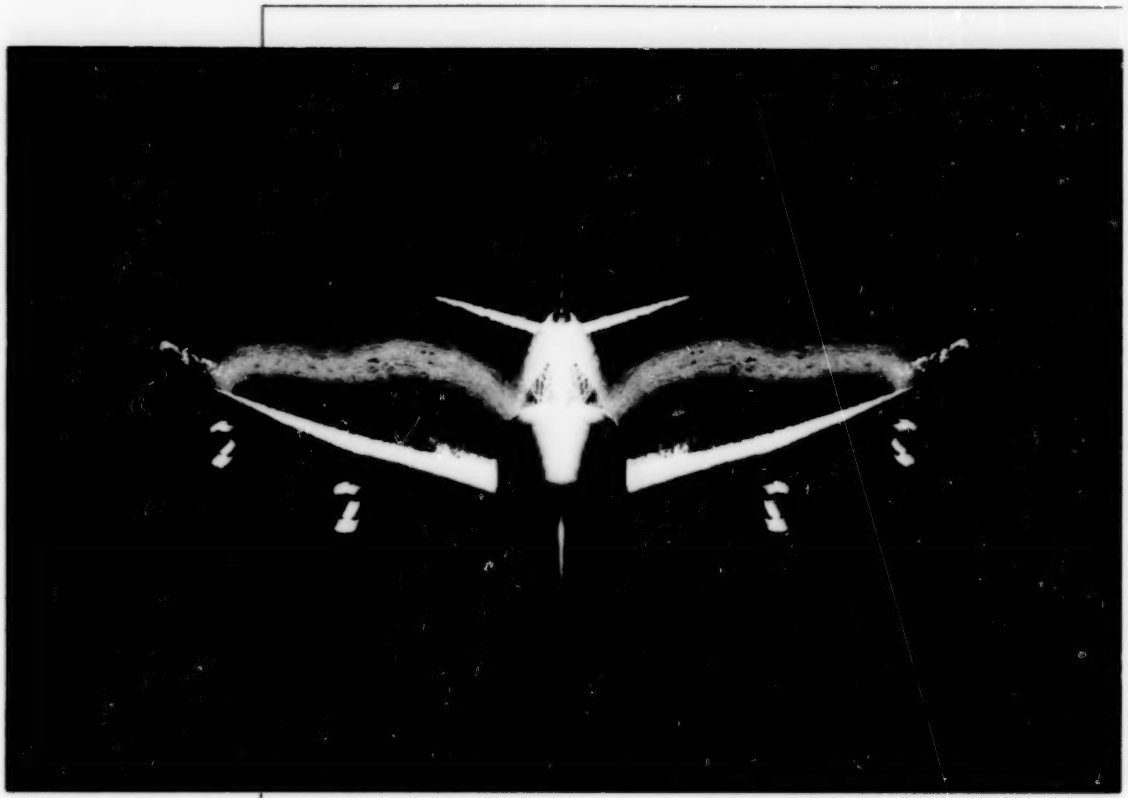
An essential first step is expansion and acceleration of NASA's aeronautical research program and transfer of the resulting new technology to the U.S. civil aircraft industry. The NASA plan contemplates the largest increase in aeronautics funding in decades: an 18 percent increase in Fiscal Year 1994 and a cumulative increase over five fiscal years (1994-98) of more than 55 percent.

"Even though air travel is a part of the private sector," said NASA Administrator Daniel S. Goldin in announcing the plan, "it should be thought of as part of the public infrastructure, just as much as the highways that private trucks and cars use in their daily business." The Administrator outlined the major elements of the NASA plan:

"Our first priority is a high speed research program leading to the construction of an economically competitive and environmentally safe high speed civil transport. It's risky and the results are uncertain. But no other step we can take is as critical to America's efforts to restore market share, provide manufacturing jobs and regain the leading edge in aeronautics.

"Our second priority is to assist in the systems integration of many emerging technologies into a new air traffic control and communications system to be incorporated into a new fleet of advanced subsonic aircraft, from transcontinental airliners to single engine planes. This will complement our traditional research into technologies that make subsonic aircraft safer, quieter, more fuel efficient and more environmentally friendly.

"Our third priority is to upgrade our national aeronautics facilities that



Symbolic of NASA's expanding program of aeronautical research is this computer-generated prediction of air pressure contours on a large transport aircraft.

underpin this research so we can regain the world class infrastructure that made America the world's aviation leader to begin with.

"Our fourth priority is continuing research into critical technologies for hypersonics...Hypersonic aircraft may be the solution to low cost access to space and may have important military capabilities."

The four high priority targets represent new focus for the NASA aeronautics program directed toward improving American competitiveness in the international marketplace at a time when U.S. plane builders are meeting greater-than-ever competition from abroad, with many thousands of jobs at stake. NASA seeks to reduce the risk of new technology and exploit the high payoff potential for reducing fuel consumption, lowering other operating costs, improving safety, reducing noise levels and satisfying environmental concerns.

The focal areas are part of a broad NASA aeronautical research and technology program that seeks to improve the performance, efficiency and environmental impact of all types of planes, from the high speed transport to the single engine general aviation airplane, and additionally addresses such infrastructure factors as air traffic control, navigation and communications. Basic research of a general nature aims at advancing aerodynamics, propulsion, materials and structures, aviation electronics and knowledge of the human factors in flight operations. Another part of the program embraces technology development for *specific* types of flight vehicles, such as the high speed transport, the tilt-rotor type of aircraft on the near horizon and high performance military aircraft. A third facet of the program seeks solutions of current and predictable aviation problems, such as reducing airplane and helicopter noise levels, finding ways to alleviate air traffic congestion and a variety of safety-related investigations.

The focal areas of the planned program are amplified on the following pages. ●

High Speed Research

A NATIONAL RESEARCH TEAM IS EXPLORING TECHNOLOGY FOR TOMORROW'S HIGH SPEED JETLINERS

Studies indicate that it is feasible to develop a High Speed Civil Transport (HSCT) airplane capable of carrying 300 people over a range of 6,000 miles at two and a half times the speed of sound, or Mach 2.5. The plane would conform to the most stringent noise standards, would not harm the atmosphere, and would carry passengers at prices competitive with those of current subsonic jetliners. ***Below*** is a McDonnell Douglas concept of a Mach 2.5 next generation airliner.

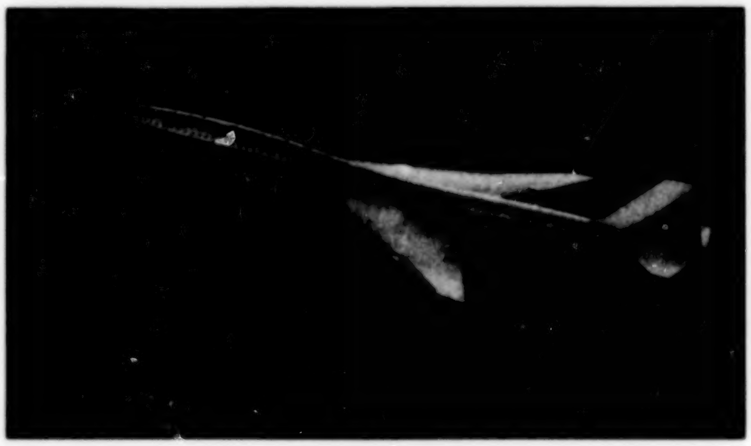
Projections indicate that the world market could support 500 to 1,000 HSCT aircraft worth $200-350 billion. If the U.S. builds the HSCT, it would mean more than 140,000 high value added jobs in the U.S. aerospace industry. But the technology development investment essential to reach the point of a production go-ahead decision is of very large order, so NASA and industry have teamed in a High Speed Research (HSR) program that addresses the highest priority, highest risk technologies needed for a HSCT, a program in the national interest that will allow U.S. industry to produce an economically viable and environmentally acceptable HSCT that could be flying by 2005.

The HSR effort is being conducted as a national team effort with shared government/industry funding and responsibilities. The team includes NASA's Lewis, Langley and Ames Research Centers and Dryden Flight Research Facility; engine manufacturers General Electric Aircraft Engines and Pratt & Whitney Division of United Technologies; airframe manufacturers The Boeing Company and McDonnell Douglas Corporation; other manufacturers, materials suppliers and academic institutions.

Phase I of the program, which focuses on environmental challenges, got under way in 1990 and will continue until 1996. A critical factor in the environmental area is demonstrating that the HSCT's emissions will not damage Earth's ozone layer. The key is to burn the fuel in a way that reduces to a very low level the generation of ozone-depleting nitrogen oxide. NASA has identified and is testing two especially promising low emissions concepts for turbine engine combustors.

In addition, research on a variety of noise suppression techniques indicates that community noise can be brought to acceptable levels. Design methods for reducing the intensity of the sonic boom have been verified by wind tunnel tests, but plans call for supersonic flight only over water. Other research shows that economic viability can be achieved in subsonic flight over land areas.

The results of Phase I indicate that technical solutions to the key environmental issues are possible. So in 1993 NASA launched Phase II of the HSR program, which focuses on economic factors associated with the HSCT. NASA and industry are addressing critical propulsion system technologies to ensure fuel efficiency and stable operation over the full range of power; airframe materials and structures technology designed to trim weight by 30-40 percent; advanced aerodynamics concepts that offer extended range through significant drag reduction; and flight deck systems for safest, most efficient operation. ●

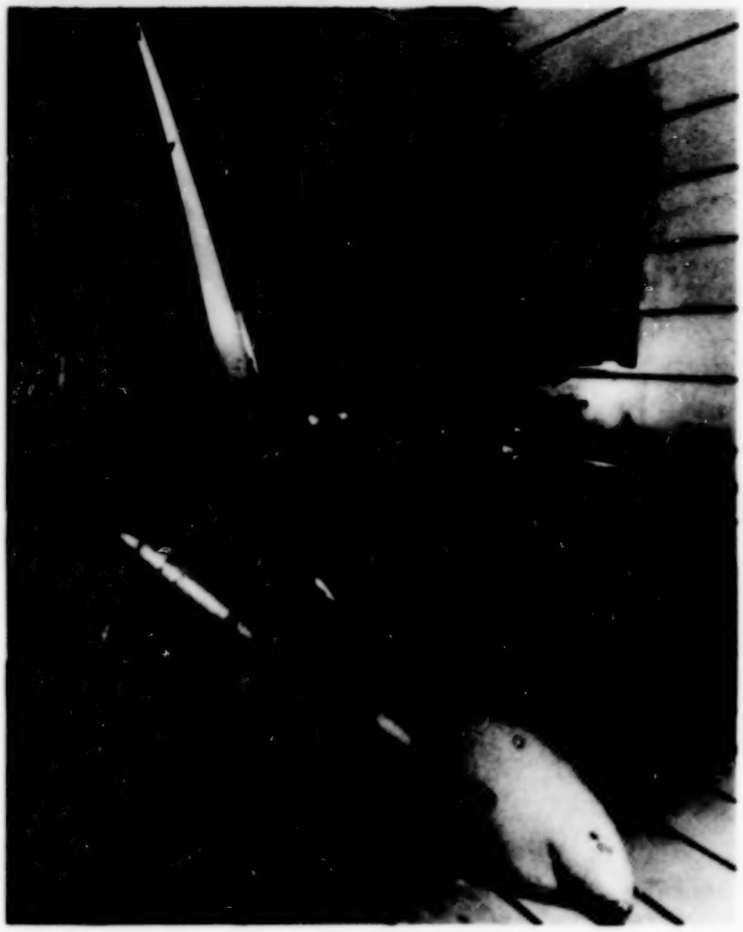


Advanced Subsonic Technology

The High Speed Civil Transport of the 21st century is expected to dominate airline service on long overwater routes, but the subsonic jetliner will continue to handle most of the overland travel, such as domestic routes within the U.S. and similar short/medium haul operations elsewhere in the world. For aircraft manufacturers, subsonic aircraft will constitute the bulk of the $800 billion —$1 trillion total market projected for the next two decades.

NASA IS DEVELOPING TECHNOLOGY TO ENHANCE FLIGHT SAFETY AND BOOST U.S. COMPETITIVENESS

Therefore, NASA, other government agencies and U.S. plane builders are engaged in an Advanced Subsonic Technology (AST) program that has two strategic thrusts: developing high leverage technologies that will assure the future competitiveness of U.S. civil transports, and finding new ways to enhance the safety and productivity of the global air transportation system. The photo ***at right*** exemplifies the type of research being conducted, a wind tunnel test of a Boeing 777 wing and engine nacelle.

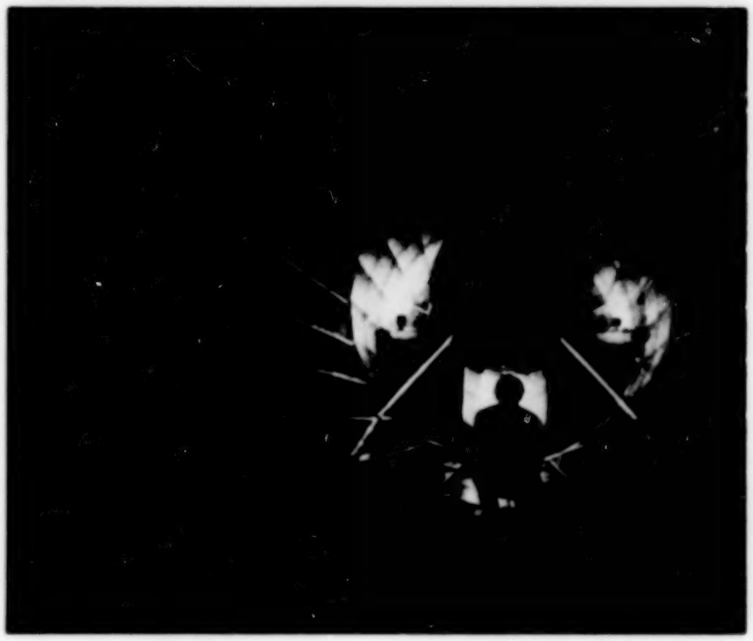


A promising technology for reducing aircraft cost and weight is advanced composite structures. NASA/industry research has led to wide use of composite materials in secondary structures such as leading edges, flaps, ailerons, fairings and access doors. Researchers feel that the technology can be extended to primary wing and fuselage structures by the end of the decade but to do that demands further effort to lower the manufacturing cost of composites. NASA's goals are a cost reduction of 20-25 percent and a weight reduction of 30-50 percent, which would result in significant benefits in operating costs.

Advanced composites technology is one of nine high-payoff technologies being investigated in the AST program. The others include fly-by-light/power-by-wire, involving development of lightweight, highly reliable optical systems that eliminate the concerns of electromagnetic interference associated with fly-by-wire; developing accurate prediction methods for determining the remaining safe structural life of aging aircraft; atmospheric modeling to assess the impact and environmental requirements for subsonic transport fleets; noise reduction; advanced propulsion systems affording 30 percent fuel savings over current engines and associated reductions in harmful emissions; improving the safety and utility of short-haul aircraft, including rotary wing aircraft; integrated wing technology, or designing major subcomponents in an integrated manner to substantially reduce cost and design time and to increase aircraft performance; and terminal area productivity, which involves development and demonstration of airborne and ground technology/procedures to reduce air traffic controller workload and safely improve the frequency of aircraft landings. The goal of the latter effort is to increase aviation system capacity at existing airports by 10-15 percent. ●

Research Facilities

One of the reasons the United States was the undisputed world leader in aviation technology for most of the 20th century was an array of national aeronautical research facilities that offered unique capabilities for aircraft design and development. Some of those facilities — wind tunnels, computational simulation centers, propulsion facilities, test beds and flight research facilities — still rank among the world's best.



NASA IS UPGRADING ITS WIND TUNNEL FACILITIES TO ENHANCE THE U.S. AIRCRAFT DESIGN CAPABILITY

Others, however, have become less efficient with age and they do not adequately represent the flight conditions expected of future subsonic and supersonic aircraft. U.S. plane builders are increasingly relying on European development facilities, some of which have capabilities and productivity unmatched in the U.S.

As the third priority of its expanded aeronautical research effort, NASA is engaged in a program of further development and refurbishing of its aeronautical facilities. An initial Wind Tunnel Revitalization program was begun in 1989, but studies indicated that something more comprehensive was needed. So NASA has undertaken a Facilities Upgrade Augmentation program that includes modernization of key facilities, design and construction planning for two new wind tunnels of advanced capability, and a study of need for additional facilities.

Wind tunnel modernization involves improvement of simulation capabilities and improvement of the tunnels' flow quality by reducing noise and turbulence. Additionally, NASA seeks to improve the productivity of its tunnels by reducing the cycle time for testing through use of automated controls, high rate data acquisition equipment, and simultaneous preparation of multiple models.

Among the key wind tunnels being modernized are the National Transonic Facility at Langley Research Center (*below*), the Unitary Plan 11-Foot Wind Tunnel at Ames Research Center, and Ames' National Full-scale Aerodynamics Complex. In design status are a subsonic wind tunnel and a transonic wind tunnel; both will feature large test sections for transport aircraft R&D, improved simulation and automated controls.

The program also includes construction of a new Composites Technology Center (CTC) at Lewis Research Center and a unique Combined Loads Test System (COLTS) at Langley Research Center. The CTC will provide advanced processing and analysis capabilities for development of high temperature composites. COLTS will provide a capability for testing full-scale fuselage structures under any type of simulated loading; it is being designed to accommodate the testing needs of the future High Speed Civil Transport and the contemplated large subsonic transports of 600-800 passenger capacity.

A NASA National Facility Study, begun in 1992, is scheduled for completion early in 1994. Its primary goal is to identify which aeronautics facilities are essential to assuring U.S. industry's civil aviation competitiveness well into the 21st century. ●

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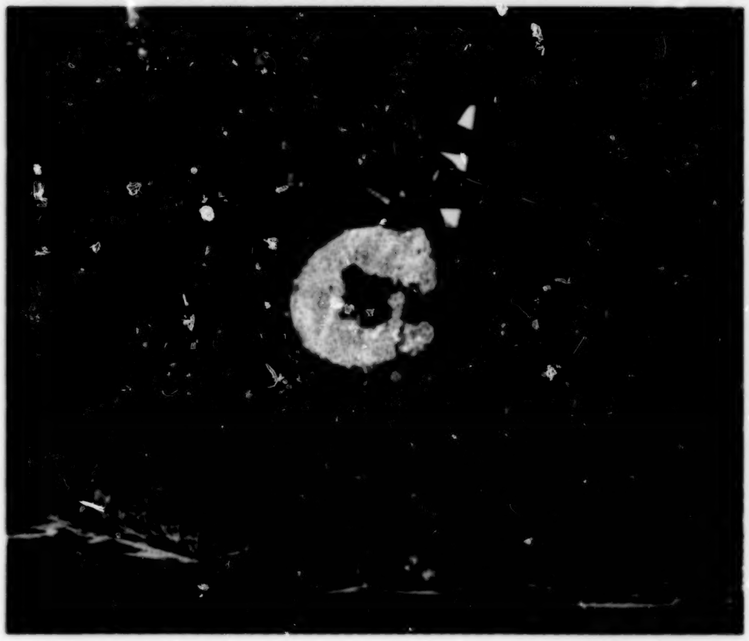
Computer Facilities

FOR IMPROVED FLIGHT SIMULATION NASA SEEKS A THOUSANDFOLD INCREASE IN SUPERCOMPUTING SPEED



For many years, aeronautical researchers have used computer design techniques to create mathematical models of flight vehicle designs and "fly" them by computer simulation, thus allowing study of many different configurations before settling on a final design. Called computational simulation, this technique has expanded enormously in recent years to embrace calculation and visual imagery of many types of forces acting upon flight vehicles, including phenomena that cannot be realistically simulated in wind tunnels. The accompanying artist's concept depicts the many types and varying pressures of airflows around a military vertical takeoff and landing aircraft.

The world's most advanced computational system is NASA's Numerical Aerodynamic Simulation (NAS) facility at Ames Research Center, a supercomputer system that links some 1,400 industry, university and government users in a high speed, wide area network. Until recently, the NAS computational capability was one billion floating points per second (FLOPS). The 1993 addition of a new Cray Y-MP C90 parallel processing supercomputer, the world's fastest, boosted the system's computer power to six billion FLOPS.

Even that level of performance, however, will not be adequate for the computational demands of tomorrow because complex future flight vehicles will be more difficult to simulate — and therefore more expensive. NASA is working toward greatly increased computer power as part of the national High Performance Computing and Communications (HPCC) program, which seeks a thousandfold increase in supercomputing speed and a hundredfold improvement in communications capability by 1997.

One approach to faster computing is parallel processing, wherein hundreds, perhaps thousands of processors work simultaneously on a problem. But increasing the number of processors does not yield a one-to-one increase in speed because the information must pass through more processors. So researchers are developing software and algorithms to break large problems into more manageable segments. By combining new mathematical techniques with parallel processing hardware, they hope to develop scalable systems in which computer speed will coincide directly with the number of processors.

The aeronautics-related segment of NASA's HPCC effort is the Computational Aerosciences (CAS) project, whose goal is improving the design and simulation of advanced aerospace vehicles at reduced cost. Because even the latest supercomputers have limitations, researchers are forced to simulate the many components of advanced vehicles separately, which is more costly and time consuming than simulating the entire vehicle at once. The CAS project seeks to improve that situation through development of new algorithms that can run on the latest parallel processing machines and allow creation of more advanced methods of modeling aerodynamics, heat transfer combustion and other elements. With advances in both software and hardware, NASA officials believe that computer speeds could reach one trillion FLOPS by the year 2000. Ames Research Center leads the CAS project, assisted by Langley Research Center and Lewis Research Center. ●

Hypersonic Research

NASA IS INVESTIGATING ENABLING TECHNOLOGIES FOR SPACEPLANES WITH AIRPLANE-LIKE FLEXIBILITY

Fourth among the priority areas of NASA's expanded aeronautical research program is hypersonic research, focused in the National Aero-Space Plane (NASP) program being conducted jointly by NASA and the Department of Defense (DoD). The NASP program is structured to develop the enabling technologies for future hypersonic and transatmospheric vehicles that offer low cost access to space.

Such spaceplanes would be airbreathing, single-stage-to-orbit vehicles capable of taking off and landing horizontally like an airplane and flying directly into orbit. They would offer space access with airplane-like flexibility and responsiveness and, because they would be fully reusable and would not need the extensive facilities and support personnel required for current vertical launches, they promise substantial reduction in operating costs. NASP technologies will also be applicable to hypersonic cruise within the atmosphere.

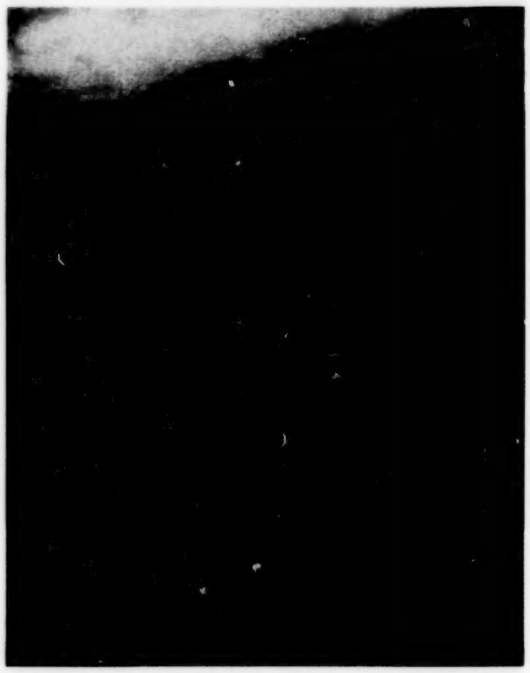
Much of the current NASP ground-based research centers on the "scramjet" (supersonic combustion ramjet) propulsion system burning a mix of hydrogen carried aboard the planned aero-space plane and oxygen scooped up from the atmosphere. Other areas of research include aerothermodynamics and computational fluid dynamics, high temperature materials and structures, integrated controls, and subsystems such as those needed for "slush" hydrogen, a higher energy mixture of liquid and solid hydrogen.

The program calls for continuing ground-based technology development and validation to support a decision in the late 1990s to fly an X-30 single-stage-to-orbit research craft (***below***). Because ground testing cannot fully simulate the flight environment above Mach 8, NASA and DoD are planning a technology risk reduction period featuring flight testing of key technologies prior to the X-30 decision. The plan involves use of subscale unpiloted research vehicles, boosted to Mach 12-15 by surplus intercontinental ballistic missiles, for tests of aeropropulsion technologies, such as those for the scramjet engine and its complex air inlet system. The experiments would advance the hypersonic technology database for high Mach numbers in three flight stages: boundary layer transition; scramjet performance; stability/controllability and airframe/propulsion integration.

The program is managed by the NASP Joint Program Office at Wright-Patterson Air Force Base, Ohio. Complementing the work of NASA and DoD is a contractor team composed of Lockheed Fort Worth, McDonnell Douglas Corporation, North American Rockwell, Pratt & Whitney Division of United Technologies, and Rocketdyne Division of Rockwell International. ●

Windshear Prediction

ADVANCED WINDSHEAR WARNING SYSTEMS ARE EVALUATED BY NASA



Windshear is a sudden shift in wind velocity and direction; its most violent characteristic is the microburst, an intense downdraft that produces strong divergent winds near the ground, typically for short duration and over a relatively small area. During takeoff and landing, a microburst can force a plane into the ground before the flight crew can take corrective action.

The Federal Aviation Administration (FAA) has mandated that commercial jetliners must have an FAA-approved system of windshear detection by 1995. Airlines can opt for "reactive" systems that employ modified versions of instruments already in service. However, such systems only advise that the aircraft is entering a microburst. NASA and the FAA are focusing on technologies that will provide 20 to 40 seconds of advance warning which, NASA research has shown, gives pilots enough time to avoid the hazard rather than cope with the turbulence of a microburst.

For several years, NASA and the FAA have jointly conducted a windshear research effort with two thrusts: to investigate the physics of windshear and develop improved models for assessing the requirements for windshear sensors, and additionally to evaluate advanced technology windshear systems. For flight testing of sensors, the program employs a Boeing 737 Transport Systems Research Vehicle (TSRV) operated by Langley Research Center. ***At left***, the TSRV is flying into a thunderstorm that may harbor microbursts; ***at right***, onboard researchers are monitoring informational displays of alert data generated by windshear sensors.

In 1991, the TSRV flew a series of missions near Denver, Colorado and Orlando, Florida to evaluate two types of warning systems, one a modified weather radar that detects sudden large changes in raindrop velocities well ahead of the airplane, the other an infrared sensor that senses the temperature differential one to two miles ahead of the aircraft.

Those two systems were tested again in 1992 along with a Doppler LIDAR (light detection and ranging) system being flown for the first time. The latter system employs an optical laser telescope to send light beams ahead of the aircraft into a storm; measurement of the energy reflected back to the telescope from tiny particles inside the storm provides an indication of windshear.

Also tested was a Langley-developed link between ground weather radar and the TSRV. Researchers are developing a system that automatically sends windshear data from ground radar to a display in an airplane cockpit, a faster and more precise technique than the current method of relaying warnings by voice. The 1992 flights represented the final phase of the program. ●

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Research Aircraft

HIGH ALTITUDE

PROBING AND CONTROL

SYSTEM EVALUATIONS

TYPIFY NASA FLIGHT

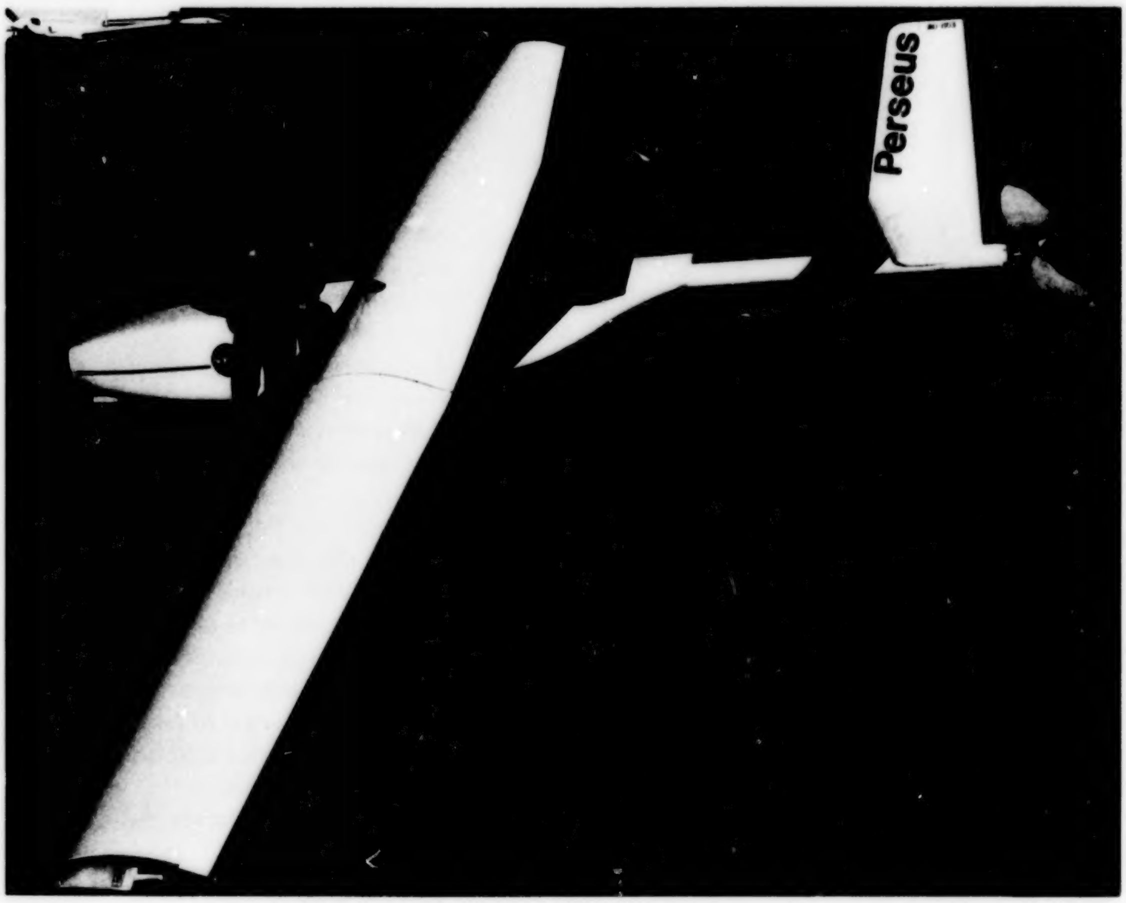
RESEARCH

Pictured ***below*** is the Perseus A, one of two Unmanned Aerial Vehicles (UAV) developed for NASA's High Speed Research program by Aurora Flight Sciences Corporation, Manassas, Virginia. Perseus was designed primarily for research in the stratosphere (above 40,000 feet), where it will carry instruments to collect information leading to development of high speed aircraft engines that have little or no effect on the atmosphere. Perseus A uses a unique closed-cycle engine powered by liquid oxygen and gasoline to achieve altitudes unprecedented for subsonic aircraft.

Perseus is representative of a fleet of research aircraft operated by NASA to explore new technologies and new flight regimes, usually in cooperation with the Department of Defense, including the Air Force, Navy, Army and the Advanced Research Projects Agency, and sometimes in cooperation with international development teams.

The UAV weighs 2,200 pounds and is capable of lifting a 250 pound payload to altitudes above 15 miles (82,000 feet) and remain on station for 60 minutes. The initial payload consists of four instruments, developed by NASA, Harvard University and Jet Propulsion Laboratory, which will sample and collect data on compounds of chlorine, ozone, nitrogen, bromine, methane and water vapor. Perseus will also acquire pressure and temperature measurements. Three scientific missions are planned for 1994, two out of the Ames-Dryden Flight Research Facility and one from Darwin, Australia.

Use of the UAV for high altitude research work is an innovation for NASA. The aircraft was selected because it offers advantages over existing ways of making high altitude measurements, particularly measurements of chemistry and atmospheric movement above 80,000 feet, a critical area in the formation and destruction of ozone. Satellites can provide broad area coverage of simple measurements, but for ozone depletion studies direct measurements taken within the ozone layer are needed.

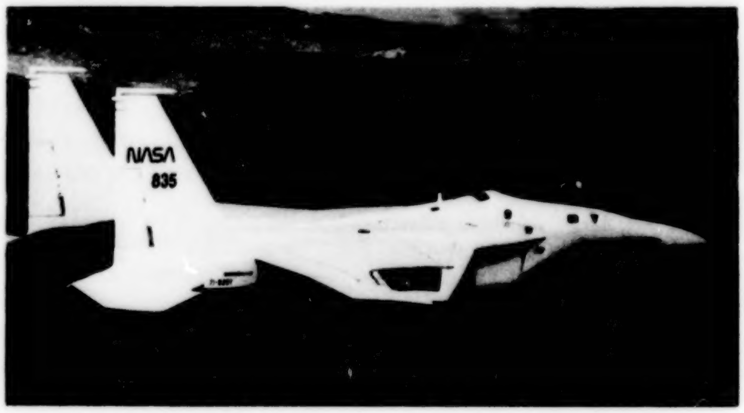


Balloons can operate at the requisite altitudes, but they are unwieldy, difficult to control and experience problems in adverse weather conditions. NASA's ER-2 research aircraft can carry a bigger payload of instruments, but it is limited to a 70,000-foot ceiling.

Pictured ***above*** is another NASA research aircraft, the Mach 3 SR-71 Blackbird, a former Air Force reconnaissance aircraft. Operating from Ames-Dryden Flight Research Facility, the SR-71 made its debut as a NASA science plane on March 9, 1993, when it carried an ultraviolet camera for astronomical studies to an altitude of 83,000 feet, allowing studies of stars, planets and comets at ultraviolet wavelengths that are blocked to ground-based astronomers.

NASA has three SR-71s, which can carry a variety of science instruments for such experiments as infrared studies of the aurora borealis and atmospheric science studies of specific pollutants in the atmosphere. In addition to its utility as a science tool, the SR-71 provides a cheaper, faster way of checking out space systems prior to their use on a spacecraft. The aircraft may also be used in support of NASA's High Speed Research program.

On May 21, 1993 at Ames-Dryden, another NASA research aircraft — a modified F/A-18 — made its initial flight. Known as the SRA — for Systems Research Aircraft — the F/A-18 is a testbed designed as a cost-lowering, time-reducing method of developmental testing for new technologies.



Its first program involved testing a "smart" electric actuator that takes signals from the aircraft's flight control computer and translates them into mechanical actions that move control surfaces, such as flaps, ailerons and rudders. A second program scheduled for the SRA involves investigation of the use of optical systems on future aircraft; NASA and industry are working on fiber optic sensors to measure the position of aircraft control surfaces, pilot input to the controls, engine temperatures and other aircraft/engine functions. A third program will involve flight tests of a new method of measuring the aircraft's speed, altitude and other air data; the new system, intended to increase accuracy and reliability, uses flush ports around the tip of the plane's nose rather than traditional sensors that protrude into the airstream and cause drag.

Also at Ames-Dryden, NASA's F-15 research aircraft (***below***) continued supersonic tests of a new electronic control system known as Performance Seeking Control (PSC). PSC monitors the plane's various computerized control systems and automatically adjusts a combination of factors —such as fuel flow and air flow into the engine — to maximize performance.

Among improvements expected from the PSC are prolonged engine life due to lower operating temperatures, lower fuel consumption at supersonic cruise, and great thrust. The benefits apply to many types of aircraft, but they have particular applicability to the High Speed Civil Transport, because the system would throttle back the engines to the lowest level necessary to sustain supersonic cruise speed. ●

ORIGINAL PAGE
C .R PHOTOGRAPH

EXPLORING THE COSMOS

On June 13, 1993, the Pioneer 10 spacecraft marked the 10th anniversary of its passage beyond the orbit of Pluto, the outermost planet of the known solar system. The most distant man-made object, the 570-pound spacecraft was 5 1/2 billion miles and more than 21 years from home port Earth — but still sending home scientific data.

As it drifts through unexplored space, Pioneer 10 is on a quest of utmost scientific importance: determining the location of the heliopause, one of the great unanswered questions in space physics. The heliopause is the boundary created by the solar wind of electrically charged particles flowing outward from the Sun and cosmic interstellar gas — a boundary that, in effect, defines the limits of the Sun's atmosphere and marks the dividing line between the solar system and interstellar space.

NASA'S BROAD SPACE SCIENCE PROGRAM SEEKS EXPANSION OF HUMAN KNOWLEDGE ABOUT EARTH AND ITS PLACE IN THE UNIVERSE

That limit was once thought to be the orbit of Pluto, but Pioneer 10 is now a decade beyond that and still within the solar atmosphere, or heliosphere (some scientists now think the boundary may be as far as 9-11 billion miles from the Sun). Pioneer 10 is also searching for evidence of a 10th planet in the solar system and, with other spacecraft, is looking for gravity waves to confirm Einstein's Theory of Relativity.

Pioneer 10 symbolizes the enormous capability NASA has developed for exploring the solar system with unmanned spacecraft. Once considered to have a design lifetime of 21 months, it has "lived" more that 12 times that span. Over its lengthy career, it has returned more than 170 billion bits of science data, and it is expected to continue transmitting at least until 1998, possibly into the next century. Built by TRW Inc., Redondo Beach, California, Pioneer 10 is managed by Ames Research Center.

Another pair of veteran solar system explorers are Voyager 1 and Voyager 2, 16 years from Earth and headed out of the solar system. Like Pioneer 10, they are searching for the heliopause and they have provided the first direct evidence of the solar system/interstellar space boundary. Since August 1992, the radio antennas on the two spacecraft have been recording intense low-frequency emissions coming from beyond the solar system. Voyager investigators believe that these radio signals are created as the electrically charged solar wind interacts with the cold interstellar gas; there is no other known space structure that could be causing the signals.

The Voyagers continue to seek an answer to exactly where the heliopause is. At midyear 1993, Voyager 1 was some five billion miles from the Sun, Voyager 2, on a different course, about 3.7 billion miles. Both have power supplies that could — with conservation measures — last another 10-15 years. The Voyager program is managed by Jet Propulsion Laboratory (JPL).

The deep space probe Ulysses will explore the heliosphere, the solar

This is an artist's concept of a historic moment on August 24, 1989 when the Voyager 2 spacecraft encountered the giant gaseous planet Neptune. Voyager 2 and its colleague Voyager 1 are 16 years from Earth on a quest of immense scientific importance: defining the boundary between the solar system and interstellar space.

wind, galactic radiation, solar/interplanetary magnetic fields and other phenomena from the fresh perspective of a never-before-penetrated region of the heliosphere — the region out of the ecliptic, the imaginary plane through the solar system that approximates an extension of the Sun's equator.

A joint NASA/European Space Agency mission managed for NASA by JPL, Ulysses was launched in October 1990 on a complicated multiyear flight path that took it in 1992 to Jupiter, where it used its unique complement of instruments to investigate Jupiter's magnetosphere for the full two weeks it took Ulysses to pass through it.

Flying within 280,000 miles of Jupiter's center, Ulysses used the giant planet's enormous gravity as a "slingshot" to accelerate the spacecraft and alter its trajectory. The maneuver propelled Ulysses out of the ecliptic plane and into an orbit that will take it ultimately over the poles of the Sun.

In June 1994, Ulysses will begin its primary mission of exploring the polar regions of the Sun and the space above the poles; the closest approach to the Sun will be about 130 million miles. Ulysses' findings are expected to revolutionize man's knowledge of how the Sun creates and controls virtually all the major processes affecting the solar system. (Continued)

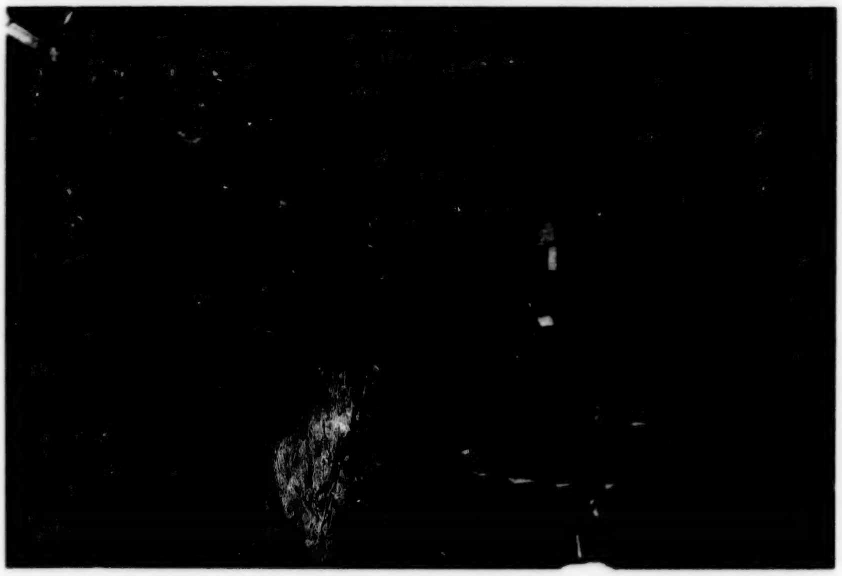
EXPLORING THE COSMOS
(CONTINUED)

At the planet Venus, the Magellan spacecraft continued the important work of mapping Venus with an advanced instrument known as the Synthetic Aperture Radar (SAR), which collected data for surface imaging, measured height variations to construct a topographic profile of Venus, and measured thermal emissions from the planet to show surface temperature variations. Magellan's findings are of prime interest to scientists, who are intrigued by the question of why Earth and Venus, two very similar planets in many respects, evolved in such dissimilar fashion.

Launched by the Space Shuttle in May, 1989, Magellan has been in polar orbit around Venus since August 1990. Since then it has conducted three SAR mapping cycles, each covering one Venus rotation or 243 Earth days. During the first cycle, Magellan mapped 84 percent of the planet's surface area. The second cycle filled in gaps in the coverage and remapped much of Venus from different angles. A test of stereo imaging (picturing the same surface area from slightly different angles) was so impressive that mission scientists recommended devoting much of the third cycle to stereo coverage. About 22 percent of Venus was imaged in stereo on the third cycle and the total coverage of the planet over all three cycles was almost 99 percent.

In Cycle 4 in 1993, Magellan's orbit was lowered to improve the quality of the gravity data that can be collected, data that can be used to infer Venus' internal structure. Magellan was able to measure the precise shape of the planet's gravity field through careful analysis of the radio signal transmitted from the spacecraft to Earth; a slowing or acceleration of the signal indicated weaker or stronger gravity. These measurements are being used to create contour maps revealing Venus' mass variations; correlation of these variations with surface features allows geologists and geophysicists to

Data from three eight-month cycles of radar mapping by the Magellan spacecraft are wrapped into this computer simulation of the planet Venus. This view is centered on the Venusian north pole; the bright spot just below the pole is Maxwell Montes, the highest mountain, which reaches more than 6 1/2 miles above average elevation. From images like this, scientists can identify terrain features such as volcanos, ridge belts, lava flows hundreds of miles long and meteor craters up to 120 miles across.



En route to an arrival at Jupiter in December 1995 is the Galileo spacecraft, which will study the Jovian system during a 23-month, 10-orbit mission around the giant planet.

study the dynamics of the planet's crust and interior. JPL is NASA's manager for Magellan.

In another solar system exploration project, the Galileo spacecraft continued on its six-year roundabout journey to the planet Jupiter. A cooperative U.S./Germany project, Galileo is a long term Jupiter-orbiting observatory that also carries a probe to investigate the planet's atmosphere.

Galileo's arrival at Jupiter is scheduled for December 1995, when the main spacecraft will fly within 620 miles of Jupiter's volcanic satellite Io to observe that scientifically intriguing body. Shortly thereafter, the Galileo probe will descend into the Jovian atmosphere and perform the first direct sampling of its physical state and chemical composition. Galileo will then initiate a 23-month long, 10-orbit mission around Jupiter, studying selected moons and the structure and dynamics of Jupiter's vast magnetosphere. JPL is overall project manager. Ames Research Center has responsibility for the probe, which was built by Hughes Aircraft.

In development status is the Cassini mission targeted for launch in October 1997. A cooperative U.S./European Space Agency (ESA)/Germany project, Cassini will fly by Venus and Jupiter enroute to an arrival at Saturn in June 2004. The spacecraft will then go into orbit around Saturn for a comprehensive, four-year orbital tour of the ringed planet and its 18 moons. In addition to instruments aboard the orbiter, Cassini will carry an ESA-built probe to investigate the atmosphere of Saturn's large moon Titan in November 2004. JPL is NASA's program manager.

Also in development is NASA's Discovery Program, which contemplates lower cost, more frequent missions to the planets by smaller spacecraft. Two initial missions are the Mars Environmental Survey Pathfinder, planned for launch in 1996, and the Near Earth Asteroid Mission, to be launched in 1998. ●

Astronomy and Astrophysics

A TEAM OF COMPLEMENTARY SPACECRAFT IS PRODUCING A COMPREHENSIVE PICTURE OF THE UNIVERSE

Shown below is NASA's Cosmic Background Explorer (COBE). Launched in November 1989, COBE is rounding out its fourth year of gathering data on fluctuations in the background radiation that courses through the universe. Since this background radiation can only be explained as a remnant of the Big Bang, the theoretical monumental explosion that began the universe some 15 billion years ago, COBE is, in effect, seeking evidence to confirm the Big Bang theory.

Early in 1993, COBE scientists reported new findings that support the Big Bang concept. Precise measurements by COBE's Far Infrared Absolute Spectrophotometer (FIRAS) show that 99.97 percent of the early radiant energy of the universe was released within the first year after the Big Bang. Radiant energy is energy emitted in any form, from x-rays and gamma rays to visible light, infrared and radio waves. FIRAS was designed to detect microwave and infrared energy from the Big Bang. COBE's evidence about the pattern of "relic" radiation and the fact that major energy releases did not occur after the Big Bang combine to make the Big Bang Theory "come out a winner," according to project scientists.

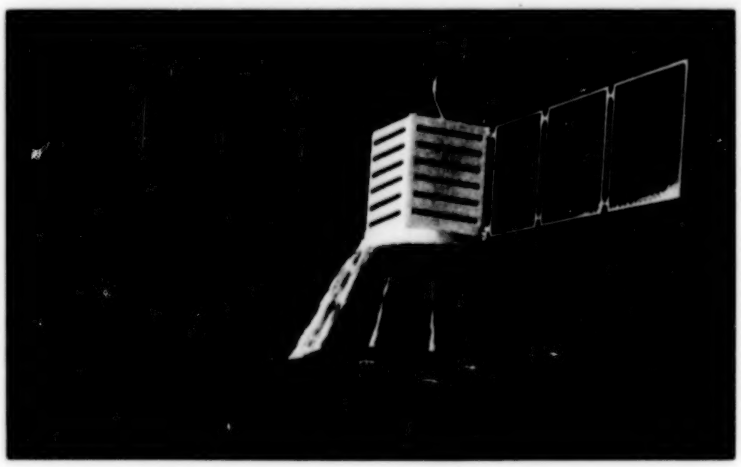
The report resulted from an exhaustive analysis of FIRAS data over 10 months of observations; hundreds of millions of measurements were combined to obtain the unprecedentedly precise results.

Managed by Goddard Space Flight Center, COBE is representative of the modern team of orbiting observatories that is contributing enormously to astronomical advancement by examining the full range of radiation in the universe and producing a comprehensive picture of the cosmos that no single observatory could provide.

The centerpiece of the advanced observatories group is the Hubble Space Telescope (HST), a cooperative program of NASA and the European Space Agency (ESA). Launched in April 1990, the HST views in the visible, ultraviolet and near infrared light ranges.

The initial spacecraft of NASA's Great Observatories series, the HST has been regularly providing astronomers exciting new information about the cosmos. It is probing the chemistry of the early universe, acquiring imagery from celestial bodies billions of light years distant, and conducting "close" observations of objects within our solar system. Of particular note are HST's discoveries supporting the hypothesized existence of black holes, exemplified by its image of the elliptical galaxy M32 showing a concentration of stars toward the nucleus that resembles the "signature" of a massive black hole. The presence of black holes in an ordinary galaxy like M32 may mean that black holes are common in the centers of galaxies.

Among the most recent HST discoveries, the telescope made the first observation of "stripped" blue stars — stars that apparently have been cannibalized of their cooler outer gas layers by other passing stars, leaving stellar "naked cores" with temperatures five times hotter than the Sun. In another assignment, the HST looked into the heart of a galaxy created by the collision of two galaxies and discovered



clusters of young stars apparently born as a result of the collision. The HST is managed by Goddard Space Flight Center, which also manages the second of the Great Observatories, the Compton Gamma Ray Observatory (***above***).

Like the HST, the Compton/Observatory has made a number of scientifically important discoveries, including the 1993 finding that powerful gamma ray bursts, one of the great mysteries of astronomy, may be far more energetic than previously thought and may originate far beyond the Milky Way Galaxy.

On Super Bowl Sunday, January 31, 1993, the observatory's Energetic Gamma Ray Experiment Telescope (EGRET) recorded a one-second burst 10 times higher in energy than any observed since the launching of Compton. Of unknown origin, the burst was 100 times brighter than the brightest steady source of gamma rays in the Milky Way and a thousand times brighter than the other known source outside the Milky Way. Since gamma rays are too energetic to be focused by mirrors or lenses, the energy and direction of a burst must be deduced and then "focused" by computer. ***At right below*** is an EGRET plot showing the probable location of the Super Bowl Sunday burst on a celestial chart; the red color marks the area of highest probability for the source location. ***At left below*** is a plot that combines observations by EGRET and the planetary probe Ulysses. The red/white ball represents EGRET data and the vertical black line is a composite position line that incorporates data from both. The probable location is centered about a point in the Constellation Virgo.

In development is the third of the Great Observatories, the Advanced X-ray Astrophysics Facility (AXAF), which will carry instruments 100 times more sensitive than the best prior x-ray observatories. Originally planned as a single spacecraft, AXAF has been restructured into two smaller, lower-cost missions that nonetheless maintain the core capability for high resolution imaging of celestial x-ray sources. The AXAF program is managed by Marshall Space Flight Center with TRW Inc. as principal contractor. Foreign participation includes Germany, The Netherlands and the United Kingdom.

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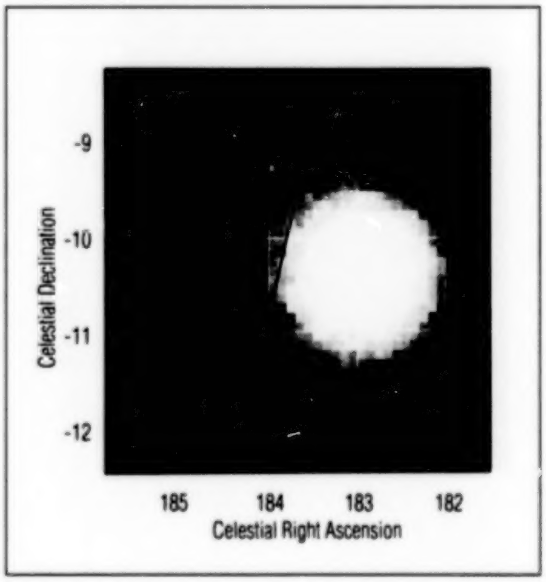
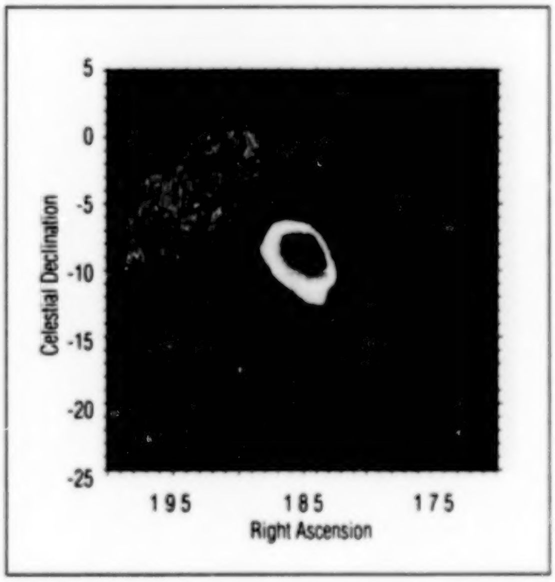




A red supergiant, the largest type of star known, is an immense celestial body, roughly estimated to be about the size of our solar system from the Sun to the orbit of Jupiter. Stellar evolution theory has long held that a red supergiant can become a supernova, an exploding star of incredible brightness, from 10 to 100 times as luminous as the Sun.

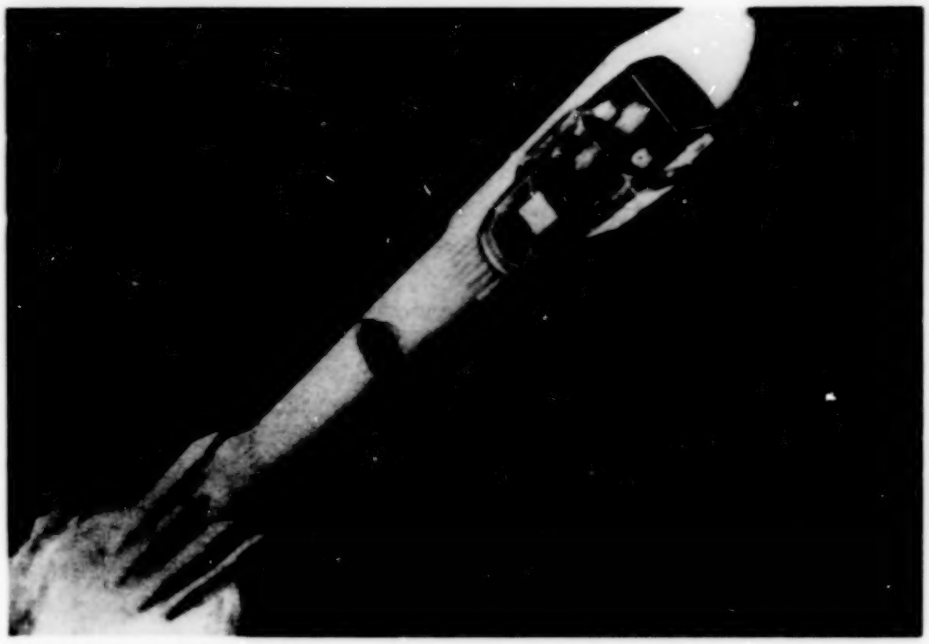
For the first time, scientists have direct evidence to confirm the theory. It came in a March 30, 1993 observation of a new supernova that occurred about 12 million light years from Earth in a galaxy known as M81 in the Ursa Major Constellation.

The discoverer was a veteran spacecraft that has been in orbit since 1978: the International Ultraviolet Explorer (IUE), a joint project of NASA, the European Space Agency (ESA) and the British Science and Engineering Research Council, managed for NASA by Goddard Space Flight Center. The IUE's observation of the supernova revealed that the exploding star is surrounded by a thick shell of slowly expanding gas heated to very high temperatures by the enormous energy released in the explosion; IUE detected the ultraviolet emissions from the glowing gas. Project scientists say they will gain information about supernovae never before available from further IUE observations and analysis of the outflowing of energy from the star; that "stellar wind" is expected to provide information about the star's life prior to the explosion, an area of great scientific interest.

A relatively new astronomical observatory –– the Extreme Ultraviolet Explorer (EUVE) pictured ***below*** — has been very active since its launch in June 1992, conducting the first full survey of the sky in a wavelength band never before comprehensively explored, the EUV band. When data analysis is complete, it is expected that more than 1,000 EUV sources will be catalogued.

Among EUVE findings is the discovery of elements that blanket the light from white dwarf stars. Astronomers have speculated that white dwarfs emit only small amounts of EUV radiation where their high temperatures should make them produce very large amounts of EUV radiation. EUVE supplied a scientifically important clue: unexpected elements — mostly iron — may work as a blanket that blocks EUV radiation and prevents its escaping into space. This is just one example of a long list of significant discoveries made by EUVE. The EUVE program is managed by

OBSERVING IN DIFFERENT BANDS OF THE SPECTRUM, SATELLITES ARE ASSEMBLING A COMPLETE MOSAIC OF SPACE RADIATIONS



Goddard Space Flight Center; the Center for Extreme Ultraviolet Astrophysics, under contract to Goddard, serves as the Science Operations and Data Analysis Facility for EUVE.

Another member of the family of advanced observatories exploring the universe in different bands of the spectrum is ROSAT, short for Roentgensatellite, a joint Germany/NASA mission launched in June 1990. Equipped with an x-ray telescope and imaging system, along with an EUV high resolution imaging system, ROSAT (***above***) is conducting a multi-year survey of x-ray sources and making dedicated observations of many specific sources.

One of ROSAT's most important observations was the discovery of a huge concentration of "dark matter." Astrophysical theory holds that most of the mass of the universe — perhaps as much as 95 percent —consists of dark matter, the precise nature of which is unknown. Dark matter emits no radiation, thus cannot be seen. Its existence is inferred from observations of visible phenomena and deductions of the gravitational forces acting on those phenomena. For example, the speeds at which certain galaxies are moving, their rotational patterns and their shapes cannot be accounted for by the possible gravitational pull of observable matter — thus it is inferred that they are being influenced by the gravity of invisible matter, dark matter.

ROSAT discovered the concentration of dark matter with x-ray images of three galaxies known as the NGC 2300 group about 150 million light years from Earth. The images show that the galaxies are immersed in a huge cloud of hot gas measuring some 1.3 million light years in diameter. Astronomers estimate that the cloud has a mass equal to 500 billion times the mass of the Sun and note that such a cloud would have dissipated into space long ago unless it was held together by the gravitational pull of an immense invisible mass of dark matter.

ROSAT's analysis allowed estimation of the amount of dark matter, and its ratio to ordinary matter, in NGC 2300. The work represents the first case in which the amount of dark matter in a small group of galaxies has been determined accurately. Further work is needed to confirm a discovery of this magnitude — repeated observations of NGC 2300 and other representative small groups of galaxies must be performed before the mystery of where most of the dark matter in the universe resides can be considered solved. ●

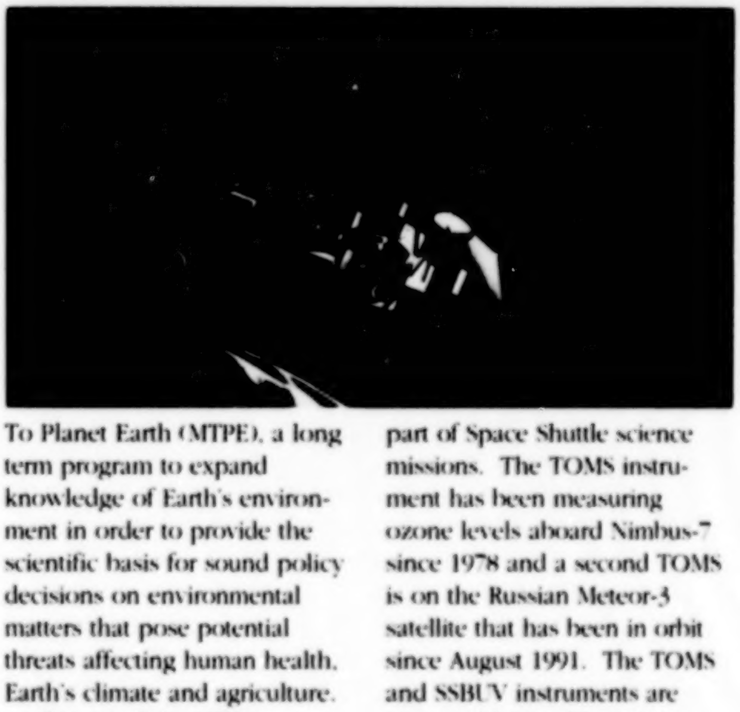
Mission To Planet Earth

OZONE AND OCEAN MONITORING HIGHLIGHT A LONG TERM EARTH OBSERVATION PROGRAM

Global ozone levels in 1992/1993 reached the lowest level ever observed, according to extensive analysis of data from NASA-developed ozone monitoring instruments. Although lower ozone values had been predicted for 1992, the actual observed values were substantially lower than predicted: in the second half of the year, global ozone was four percent lower than normal and two to three percent lower than any previous year.

NASA's ozone watch represents one facet of the Mission To Planet Earth (MTPE), a long term program to expand knowledge of Earth's environment in order to provide the scientific basis for sound policy decisions on environmental matters that pose potential threats affecting human health, Earth's climate and agriculture.

Phase I of the MTPE program has been under way since September 1991. It embraces data gathering by such NASA satellites as Nimbus-7 and the Upper Atmosphere Research Satellite (***above***), by NASA instruments aboard satellites of the National Oceanic and Atmospheric Administration and foreign nations, by Space Shuttle-based instruments, and by airborne and ground-based studies. This broad study of Earth's land, sea, oceans and ice will pave the way for Phase II, planned for initiation late in the decade, which will provide broader coverage with the multi-satellite Earth Observing System (EOS).

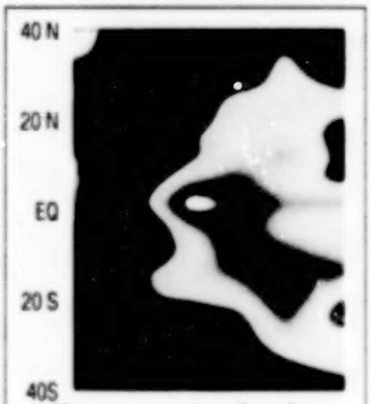


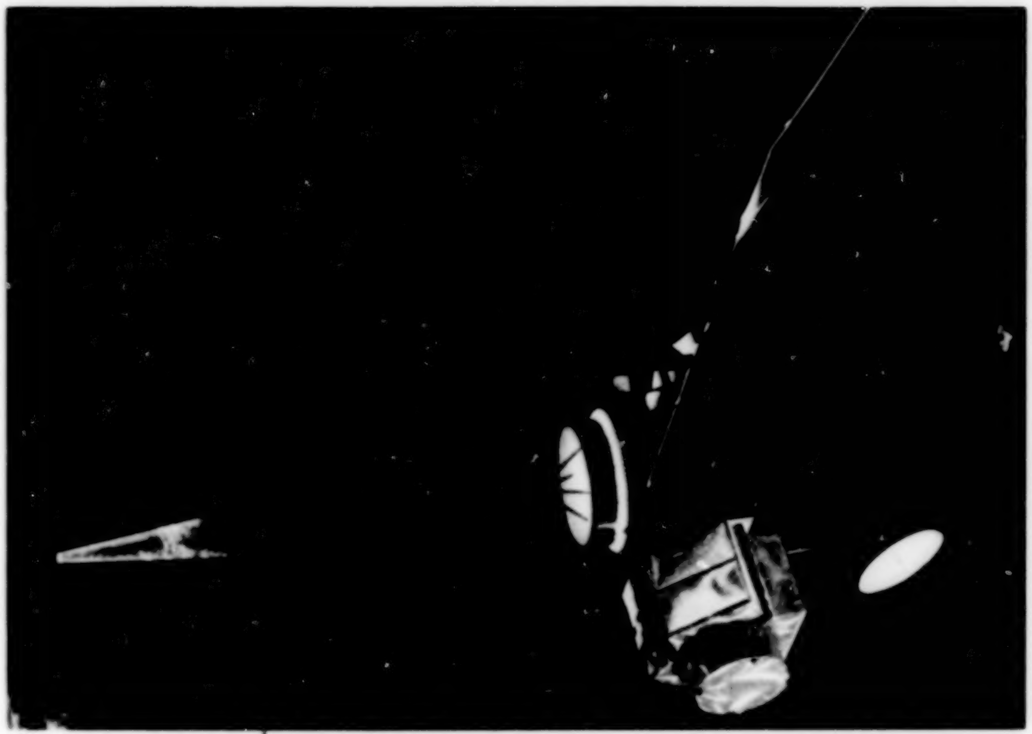
The 1992/93 ozone data were supplied principally by an ozone-monitoring instrument known as TOMS (Total Ozone Mapping Spectrometer) and a Shuttle Solar Backscatter Ultraviolet (SSBUV) instrument flown annually since 1989 as part of Space Shuttle science missions. The TOMS instrument has been measuring ozone levels aboard Nimbus-7 since 1978 and a second TOMS is on the Russian Meteor-3 satellite that has been in orbit since August 1991. The TOMS and SSBUV instruments are managed by Goddard Space Flight Center.

Scientists can only speculate on the cause of the lower ozone values in 1992/93. One speculation is that it may be related to the continuing presence of particles produced in the upper atmosphere by the June 1991 eruption of Mount Pinatubo in the Philippines. That eruption is under study by another MTPE satellite, the Earth Radiation Budget Satellite (ERBE), which found that stratospheric dust created by Pinatubo resulted in a temporary cooling of Earth's surface temperature of approximately one degree Fahrenheit.

The cooling occurred because some of the Sun's rays never reached Earth's surface; they were reflected back into space by the veil of fine volcanic ash. ERBE observations of incoming solar radiation over a six-month period following the eruption (***below***) show a dramatic increase in the amount of energy reflected back to space; the image shows increased reflection in July (yellow) and further increased reflection in August-October (yellow and red).

ERBE measurements provide the data needed to understand the link between volcanic ash and global surface temperature changes. While the ash cloud cools the surface, it can also produce an opposing greenhouse warming effect by trapping infrared radiation emitted by Earth. ERBE directly observes changes in emitted infrared and reflected solar radiation, enabling scientists to





calculate the net effect on surface temperature. Launched in 1984, ERBE is managed by Langley Research Center.

Among the newer MTPE data collecting systems is the U.S./France Ocean Topography Experiment known as TOPEX/Poseidon (***above***). Launched in August 1992, TOPEX/Poseidon produced the first map of ocean topography in 1993. The satellite is addressing how ocean circulation influences global climate. By mapping the circulation of the world's oceans over several years, TOPEX/Poseidon will help scientists better understand how oceans transport heat, influence the atmosphere and affect climate. The NASA portion of the TOPEX/Poseidon program is managed by Jet Propulsion Laboratory (JPL).

Another MTPE satellite seeks greater knowledge about how the tectonic plates that make up Earth's crust are moving and how the motion of these plates causes surface deformation and earthquakes. LAGEOS II, launched from the Space Shuttle in 1992, is a cooperative U.S./Italy satellite program tracked by the NASA-led International Global Geodetic Network. The satellite is covered with hundreds of reflectors that "bounce" laser pulses beamed from Earth stations back to their sources. Measurement of the time it takes a pulse to travel to the satellite and back to Earth allows high accuracy determination of the ground station's position. Repeated measurements of many stations over years and over wide geographic areas will tell scientists how far and how rapidly the Earth stations moved from each other, thus allowing determination of plate motions and local crustal deformation. Since most earthquakes and volcanic eruptions occur where plates meet, LAGEOS II is expected to shed light on how these cataclysmic events occur and where they are likely to happen.

The centerpiece of MTPE is the Earth Observing System (EOS) program, a series of spacecraft of highly advanced data gathering capability intended to make the first long term, comprehensive measurements of the interrelated elements of the global environment. These measurements, along with ground observations and other scientific research, will enable scientists to model Earth as a global system and to project how human activities and natural events have affected and will affect the planet. The first two EOS sensors will fly on a US/Japanese satellite, and the first EOS satellite is targeted for launch in June 1998.

The EOS program, which will generate an enormous flow of data, clearly requires an advanced data processing system to analyze and move data from a great many U.S. and foreign spacecraft to researchers across the U.S. and around the world. The system is known as EOSDIS (Earth Observing System Data and Information System). In March 1993, NASA started development of a key component of the system — the EOSDIS Core System, or ECS — with award of a contract to Hughes Applied Information Systems, Seabrook, Maryland for design, development and operation of the ECS. ●

Sun/Earth Relationships

THE EARTH-INFLUENCING CHARACTERISTICS OF THE SUN ARE THE SUBJECT OF A MULTINATIONAL INVESTIGATION

An important facet of NASA's space science program is solar-terrestrial research, which is not only of special scientific interest but also has practical implications for Earth's climate, weather and other life-influencing factors. Solar-terrestrial research embraces the study of the Sun as a variable star (one whose activity varies over time); the origin and transmission of the solar wind, the stream of hot gas that courses through the solar system; the transfer of solar wind energy to Earth and all the planets; the interaction of the solar wind with Earth's magnetic fields and the subsequent effect on Earth's lower atmosphere.

Exploration of Sun/Earth relationships is a multinational collaborative effort known as the International Solar Terrestrial Physics (ISTP) program, being conducted jointly by NASA, the European Space Agency (ESA) and the Japanese Institute of Space andAstronautical Science. The ISTP program was inaugurated in 1992 with the launch of Geotail, a Japanese satellite carrying U.S. instruments, managed for NASA by Goddard Space Flight Center. Geotail is pictured ***below*** undergoing preflight checkout.

Geotail's mission is to investigate the interaction of the solar wind and Earth's magnetosphere, in particular the transformation and storage of energy in Earth's "magnetotail," which stretches out for millions of miles on the night side of the planet. Geotail employed a series of lunar gravity assists that enable the satellite to orbit on the night side of Earth in a wide path that takes it at times more than a million miles from Earth. The spacecraft's instruments measure the flow of energy in the magnetotail, seeking to clarify the mechanisms that control the input, transport, storage, release and conversion of energy. This represents one portion of a comprehensive multiyear ISTP program whose overall aim is to gain broader understanding of solar terrestrial physics in order to develop a capability for predicting how Earth's atmosphere will respond to changes in the solar wind.

A related space physics investigation is being conducted by NASA's SAMPEX (Solar Anomalous and Magnetospheric Particle Explorer), the first of a new series of Small Explorer missions that will enable scientists to develop less costly science experiments in a shorter period of time. SAMPEX is designed to contribute new knowledge about the evolution of the Sun, the solar system and galaxies.

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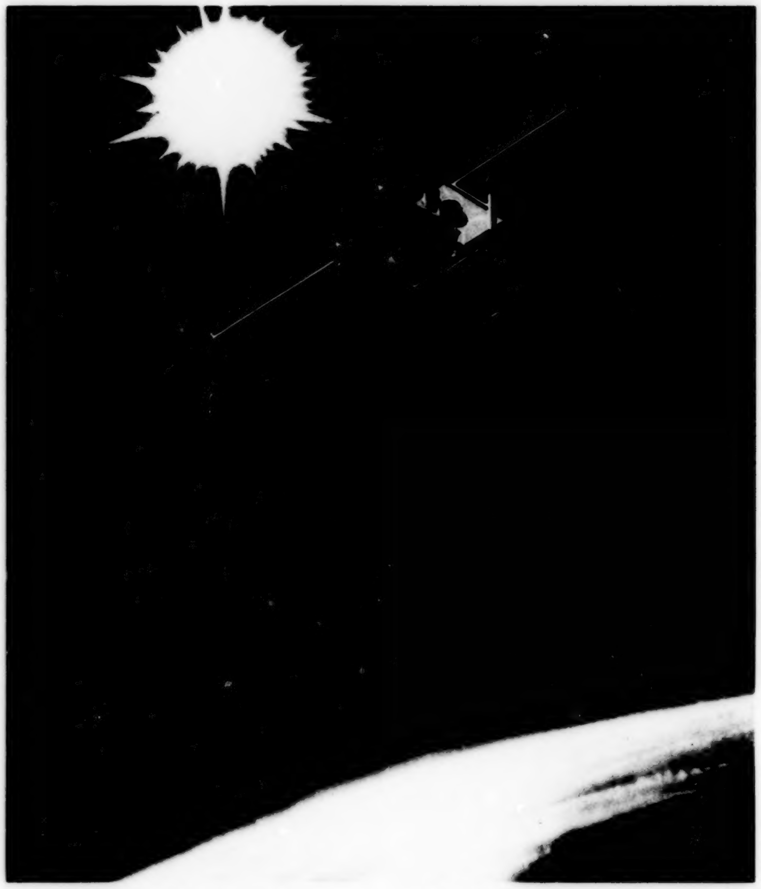


SAMPEX (***above***) was launched in July 1992 into an elliptical orbit that allows the satellite's instruments to use Earth as a giant magnetic shield, making it possible for the four instruments to determine whether the particles it detects are coming from the Sun or the Milky Way Galaxy, or whether they are "anomalous" cosmic radiations resulting from the Sun's interaction with stellar gas.

In 1993, SAMPEX discovered and pinpointed a belt of anomalous cosmic ray particles several hundred miles above Earth, confirming an earlier indication that such a belt existed. The anomalous belt is composed of different types of high energy particles than those in the Van Allen radiation belts discovered in 1958 by the Explorer 1 satellite, and it is embedded within the innermost of the two Van Allen belts.

SAMPEX scientists explain that the cosmic rays become trapped in Earth's magnetic field and that trapped radiation can be stored for weeks or more, so the intensity can build up over time as more arrive. More of the cosmic rays collect in the belt during periods of minimal solar activity, which follows an 11-year cycle. Long term storage of trapped radiation gives the SAMPEX team a unique opportunity to study the properties of interstellar matter "right in Earth's back yard." SAMPEX is managed by Goddard Space Flight Center.

Also engaged in Sun/Earth studies is NASA's Soft X-ray Telescope (SXT), which is carried aboard the Japanese satellite Yohkoh. Launched in August 1991, Yohkoh and SXT are studying solar flares and the Sun's corona, the outer solar atmosphere where flares occur. The SXT is producing images of flares, studying the evolution of coronal structure, and measuring variations in the Sun's brightness. The SXT will also provide correlative measurements of solar wind source regions when the Ulysses spacecraft (see page 21) investigates those sources in 1994/95. ●

COMMERCIAL USE OF SPACE

A principal element of NASA's effort to stimulate commercial use of space is a network of Centers for the Commercial Development of Space (CCDS), established to enlarge the technology base on which to build new commercial space industries and to help move emerging technologies from the laboratory to the marketplace with speed and efficiency.

The CCDS are NASA-sponsored not-for-profit research consortia composed of industrial firms, academic institutions and government organizations. Since the program was initiated in 1985, the number of centers has grown to 17 and the list of industrial participants to about 200. Each CCDS specializes in a particular discipline: four are engaged in space materials processing, three in life sciences, two in remote sensing, two in automation and robotics, two in space power, two in advanced communications, one in space propulsion, and one in space structures and materials.

TO BOOST U.S. COMPETITIVENESS, NASA SEEKS TO EXPAND PRIVATE SECTOR INTEREST AND INVESTMENT IN SPACE

The aim of the CCDS is to identify technologies that have sufficient promise of commercial acceptance to warrant their flight testing in the space environment, then to conduct flights to mature the technology to the point where a decision can be made as to the practicability of commercial development. Much of the CCDS research is accomplished by secondary payloads carried in middeck lockers aboard the Space Shuttle Orbiter, or in the new Spacehab pressurized laboratory introduced in 1993 (see page 36). The types of research being conducted by the CCDS are exemplified by the experiments carried in the Spacehab facility on its maiden voyage, Shuttle mission STS-57 flown by the Orbiter *Endeavour* in June 1993.

Among those experiments was one directed toward sustaining plant growth in space for use in a long term life support system in which plants would provide food, oxygen and pure water, remove carbon dioxide from the air and recycle waste products for reuse as the raw materials of growth.

A researcher's ability to conduct plant biotechnology activities in space is dependent on the development of space hardware capable of providing the environmental conditions needed to support plant growth effectively. Such a system is being developed by one of NASA's CCDS, the Wisconsin Center for Space Automation and Robotics (WCSAR), located at the University of Wisconsin, Madison. WCSAR is teamed with four Wisconsin-based industrial partners: Quantum Devices, Inc. (Barneveld), Orbital Technology Corporation (Madison), Automated Agriculture Associates, Inc. (Dodgeville) and Biotronics Technologies, Inc. (Waukesha). The flight hardware is known as the Astroculture™ system; it is necessary to test it in orbit because Earth-based evaluations cannot substantiate hardware performance under long term low gravity conditions.

The STS-57 mission marked the second flight test of the Astroculture unit. A July 1992 test was the first successful demonstration of a system that could provide water and nutrients for plants for extended periods in space. The STS-57 flight allowed evaluation of performance aspects not studied during the earlier test, such as the light emitting diode technology for photosynthesis research (see page 69) developed by the WCSAR partnership. A third flight is scheduled for late 1993.

STS-57 also carried a number of CCDS biotechnology experiments, including test of a system named ORSEP (Orbital Separation) designed to enhance the purity of drugs and other materials, thus enabling use of smaller quantities of cell-produced drugs with reduced side effects. ORSEP is being developed by a group composed of two CCDS — the Consortium for Materials Development in Space, University of Alabama, Huntsville, and the Center for Cell Research, Penn State University — and two industrial partners: Space Hardware Optimization Technology, Inc., Floyd Knobs, Indiana and Interfacial Dynamic Corporation, Portland, Oregon.

ORSEP separates cells and particles with a process available on Earth but uses the low gravity of space to improve the separation process and enhance purification. When certain water solutions are mixed in space, the two fluids separate, much like oil and water. During this process, fluids that contain impure biological materials concentrate in one fluid or at the boundary between the two fluids, thus allowing the impurities to be removed.

Representative of the broad variety of projects being conducted by NASA's Centers for the Commercial Development of Space is the Wake Shield Facility; a free flying laboratory for growing high purity crystals in space (see page 37).

Another CCDS — BioServe Space Technologies, University of Colorado, Boulder — sponsored two experiments on STS-57: the Commercial Generic Bioprocessing Apparatus (CGBA) and the BioServe Pilot Laboratory (BPL). Companies teaming with BioServe in these developments include Abbott Laboratories, North Chicago, Illinois; Aquatic Products International, Lincoln, Nebraska; Chiron, Emeryville, California; Martin Marietta, Denver, Colorado; OmniData International, Logan, Utah; Spaceport Florida Authority, Cocoa Beach; Synchrocell, Silver Spring, Maryland; Spalding Labs, Arroyo Grande, California; and Water Technologies, Plymouth, Minnesota.

The CGBA is a multipurpose facility designed to help scientists better understand the relationship of gravity and biology. On STS-57, its third use in orbit, the CGBA carried eight biomedical test models to collect information on how microgravity affects biological organisms. Test model results are expected to provide information toward better knowledge of certain diseases and disorders, including cancer, AIDS and osteoporosis.

The BPL is a testbed designed to provide the commercial and scientific research communities affordable access to orbital materials and life sciences research. On STS-57, it housed a series of investigations of bacterial products and processes to determine changes in growth and behavior due to the absence of gravity. Better understanding of bacterial development processes is expected to lead to increased opportunities for future enhanced genetic engineering and improved pharmaceutical production. (Continued)

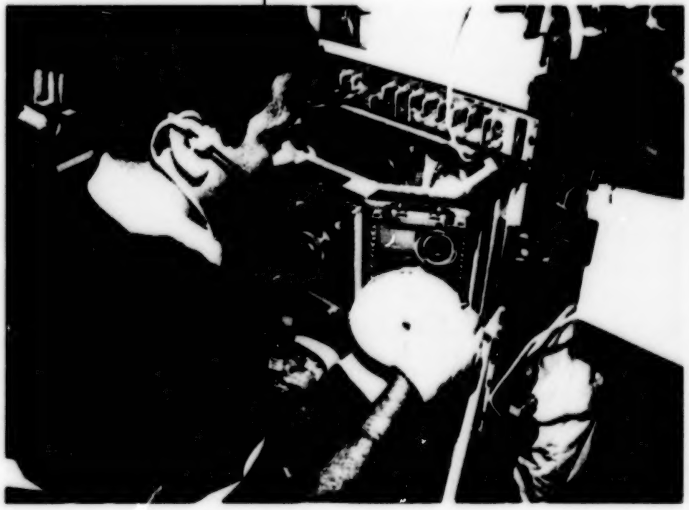
™ Astroculture is a trademark of the Wisconsin Center for Space Automation and Robotics.

An activity of considerable emphasis among NASA's Centers for the Commercial Development of Space (CCDS) is growing large, pure, uniform and precisely ordered protein crystals, which are much in demand by pharmaceutical companies for drug research and drug delivery. Structural information gained from protein crystals yields clues to better understanding of human body processes, for example, the immune system and the function of individual genes, knowledge that could spur development of advanced drugs for treatment of many diseases. Research indicates that crystals grown in microgravity conditions are superior and larger and offer a greater capability of determining a protein's molecular structure than do crystals grown in Earth's gravity.

On the June 1993 STS-57 Space Shuttle mission, the Spacehab facility carried protein crystal growth experiments developed by the NASA sponsored Center for Macromolecular Crystallography and its industrial partners: BioCryst Pharmaceuticals, Inc., Birmingham, Alabama; Eli Lilly & Company, Indianapolis, Indiana; Schering-Plough Research, Bloomfield, New Jersey; Du Pont Merck Pharmaceuticals, Wilmington, Delaware; Sterling Winthrop, Inc., Malvern, Pennsylvania; Eastman Kodak Company, Rochester, New York; The Upjohn Company, Kalamazoo, Michigan; Smith Cline Beecham Pharmaceuticals, Philadelphia, Pennsylvania; and Vesta Pharmaceuticals, Inc., Cambridge, Massachusetts.

Examples of the types of research being conducted by the Center for Macromolecular Crystallography are determination of such protein target structures as elastase and gamma interferon. The elastase protein enzyme, produced by the human body, sometimes goes awry, attacks and destroys lung tissue. The first goal of the center's work is to determine the elastase structure with x-ray crystallography; an associated goal is to develop an inhibitor that could be used as a medicine to combat lung disease. The gamma interferon protein serves as a regulator of white blood cell activities and aids the body's defense against infections and cancer cells. With the refined structure obtained from space grown crystals, the center and its partners may be able to develop medicines that mimic gamma interferon's action against disease. This work was advanced by experiments carried aboard STS-57, results of which are being analyzed.

A different type of crystal growth research is focused on zeolites, crystals that can be used in industrial, medical and environmental purification and catalytic processes. As purifiers, zeolites work as a "molecular sieve" to remove contaminants. As catalysts, zeolites aid in making indus-



The potential of space-grown protein crystals in pharmaceutical development is being enhanced by new techniques which allow control and modification of crystal growth conditions during a Space Shuttle mission. Some space-grown crystals are shown in the near photo; at left, payload specialist Dr. Larry DeLucas, a leading contributor to crystal growth optimization, is controlling crystal growth on a Shuttle mission.

trial processes more efficient. Zeolites have wide and important applications in such areas as making fossil fuels more efficient and more environmentally acceptable; cleaning up the world's threatened water supplies; and providing a safe and effective way of disposing of radioactive wastes.

The enormous potential of zeolites has sparked interest among America's space competitors. Access to large, defect-free zeolite crystals — and the knowledge gained from studies of such crystals — could provide U.S. companies very important competitive advantages.

Two NASA CCDS — Battelle Advanced Materials Center, Columbus, Ohio and Clarkson Center for Commercial Crystal Growth, Potsdam, New York — teamed with a number of industrial and academic affiliates to fly 38 sample zeolite solutions in a 1992 Shuttle mission. Results of that flight were applied to a zeolite growth experiment package flown aboard STS-57 in June 1993.

Zeolite crystals, which have significant commercial potential, can be grown larger and with fewer defects in orbit. This photo compares orbit-grown (top) and Earth-grown crystals.

Battelle is conducting related research in its work on polymer membranes, thin plastic films that have broad commercial applicability in such areas as desalination of water, filtration of impurities, purification of atmospheres, electrolysis and kidney dialysis, and production of ultrapure drugs for improved treatment of intractable diseases. The Battelle center has sponsored experiments on eight Space Shuttle missions since 1990, including STS-57, and at least one more Shuttle-based experiment is planned.

The research has yielded important discoveries, as evidenced by patent applications filed by the center. Among Battelle's industrial partners are Amoco Chemical Corporation, Napierville, Illinois; Du Pont, Wilmington, Delaware; and Bend Research, Bend, Oregon.

One more example of a CCDS experiment on STS-57 was a test of the ECLiPSE (Equipment for Controlled Liquid Phase Sintering Experiment) research package developed by the Consortium for Materials Development in Space, University of Alabama in Huntsville. ECLiPSE resulted from an industry need to understand better the process of liquid phase sintering. The project focuses on producing combinations of hard metals in a tough metal matrix to get a metal with the much sought wearing properties of the hard material and the strength of the tough material. It could lead to a range of new or improved products such as stronger, lighter, more durable metals for bearings, cutting tools, electrical brushes, contact points, and irregularly shaped mechanical parts for high stress environments. ●

Shuttle Experiment Module

Designed to meet a need for additional experiment space in the Space Shuttle Orbiter, the Spacehab pressurized augmentation module made its debut aboard Shuttle flight STS-57, launched June 21, 1993. Carried in the Orbiter's payload bay and accessed through an airlock (***below***), the laboratory increases by four times the available experimentation space where astronauts can work, and offers relatively low cost access to orbit on a commercial basis.

Marketed by Spacehab, Inc., Arlington, Virginia, the module was developed entirely with private capital. McDonnell Douglas Space Systems Company conducted the design, development and production of the modules under contract to Spacehab and also handles ground integration for flight experiments.

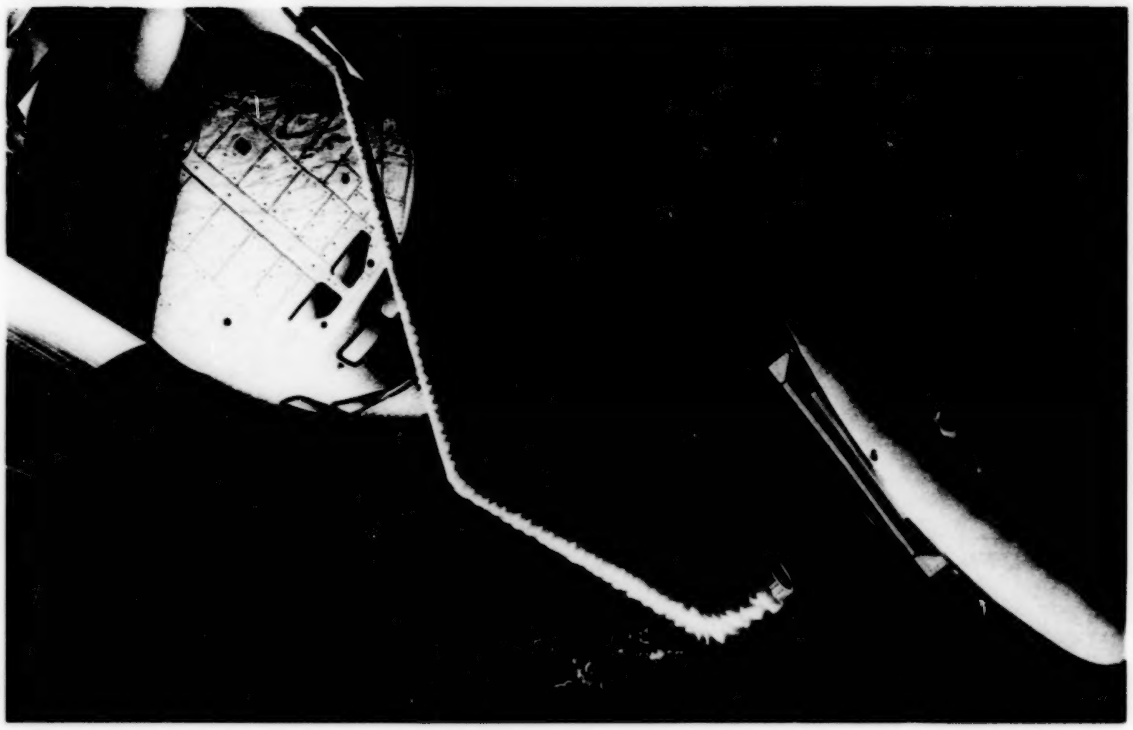
On the inaugural flight aboard the Orbiter *Endeavour*, the module carried a full load of experiments, more than a score of them sponsored by NASA's Centers for the Commercial Development of Space (see page 32). Under a NASA/Spacehab agreement, the modules will be carried on eight Shuttle flights. Spacehab will pay NASA for launch services and lease experiment space; 43 lockers were in use on the debut flight. Spacehab is marketing locker space and payload integration services to U.S. government agencies, foreign governments, industry firms, universities and brokers.

The Spacehab module is 13.5 feet in diameter, about nine feet long and has 1,110 cubic feet of volume. The module and the airlock together occupy less than one-third the length of the Orbiter's payload bay, leaving ample room for primary experiments. ●

A NEW LABORATORY MODULE OFFERS A FOURFOLD INCREASE IN SPACE SHUTTLE PRESSURIZED WORK SPACE

Wake Shield Facility

A SHUTTLE-BASED FACILITY ALLOWS GROWTH OF SUPER-PURE CRYSTALS



A good part of the materials processing research conducted in orbit has been directed toward taking advantage of the microgravity environment to grow high purity crystals for more powerful semiconductors. Space Shuttle mission STS-61 in late 1993 marks the start of a new phase of orbital materials processing in which researchers will explore the potential of gallium arsenide crystals grown in high vacuum to achieve an unprecedented degree of purity. In theory, semiconductors made from such crystals could conduct electricity 8-10 times faster than silicon chips.

The technology being explored is known as molecular beam epitaxy, which means growing crystals in a special atom-by-atom, layer-by-layer manner to produce varying crystalline structures. Epitaxial growth under orbital high vacuum conditions offers potential for production of crystalline thin films of higher quality and greater purity than can be produced on Earth. In addition to computer uses, such films offer promise of important advances in lasers, infrared devices, communications systems and other microelectronic applications.

The research is being conducted by the Space Vacuum Epitaxy Center (SVEC), University of Houston, Texas, one of NASA's Centers for the Commercial Development of Space. SVEC's principal research tool is a novel spacecraft called the Wake Shield Facility (WSF), a 12-foot diameter disc (***above***) with its own power, command and control units. Carried in the payload bay of the Shuttle Orbiter, the WSF is deployed in low Earth orbit, operated remotely by Shuttle astronauts and later recovered by the Orbiter's remote manipulator arm.

Its job is to create a superior vacuum. Although low Earth orbital space is technically a vacuum, it actually contains traces of atmosphere that could contaminate crystal growth. The WSF, sweeping through space at orbital velocity, brushes aside the trace particles and fashions a wake, like the wake of a boat in water. This creates an "empty" space immediately aft of the disc, an ultravacuum region where near perfect gallium arsenide crystals can be grown. The STS-61 mission is intended to prove the concept; three additional missions are planned for producing gallium arsenide crystals in volume. ●

Vineyard Protection Research

California's winegrowers are facing a serious crisis from infection of their vines by the phylloxera aphid, a root louse that kills grapevines by sucking the juice from the plants' roots. Infestation has destroyed thousands of acres of vineyards and further devastation is threatened, because about 65 percent of the vineyards in California's Napa and Sonoma counties are planted with a rootstock that is vulnerable to phylloxera.

However, starting in 1993, a government/industry/university research team is fighting back with a three-year technology demonstration that may provide a way to mitigate the damage through early detection by application of remote sensing techniques in concert with ground research. Managed by Ames Research Center in cooperation with Robert Mondavi Winery of Napa Valley, the project is known as Grapevine Remote Sensing Analysis of Phylloxera Early Stress (GRAPES).

Scientists will first conduct ground research to establish the relationship between the nutrient content of a grapevine leaf and its spectral response. Then airborne sensors will be employed to overfly large areas and provide an assessment of the extent of infestation based on nutrient deficiencies sensed. ***Below***, Ames Research Center scientist Dr. Roy Armstrong is selecting a grapevine leaf for laboratory analysis of its spectral response and chemistry. ***At right***, researchers from Ames and California State University, Chico, are examining a phylloxera-infested vine.

The plants are being attacked by unseen phylloxera aphids that live almost entirely underground attached to the roots of the vines. It takes two to three years before the aboveground part begins to show visible signs of sickness — such as yellowing leaves and failing grape production — and by that time the infestation may have spread far. Pesticides are ineffective because they penetrate only three to five feet below the surface, and phyllox-

REMOTE SENSING TECHNIQUES ARE BEING APPLIED TO EARLY DETECTION OF GRAPEVINE STRESS

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era aphids live 10 to 12 feet underground.

The only way to rid the vineyards of the pest is to replant with phylloxera resistant roots. That costs about $20,000 an acre — but the overall cost can be substantially reduced if remote sensing can detect infestation early, before it has spread too far.

The GRAPES project got under way in April 1993, when ground-based scanners were employed to make images of both infested and non-infested vines to establish the earliest detectable spectral differences between healthy vines and sick vines. In May, the team began acquiring imagery from a Landsat satellite and in June a variety of aircraft started imaging flights.

GRAPES is employing a multi-sensor, multi-scale approach to measure several early indicators of plant disease. Scanners that record the visible and near-infrared light from grapevine leaves will detect very early nutrient deficiencies that would not become apparent to visual inspection until much later. Thermal scanners will also record subtle differences in grapevine temperatures, an indicator of plant health; stressed plants are warmer because they cannot effectively pass water through their membranes.

Satellite and aircraft-based imagery, used in combination with a computerized data base, will provide overviews of how, where and why phylloxera spread and lead to development of "risk maps" that will enable winegrowers to better manage the replanting process; with effective early detection, it may be necessary to replant only a few acres, rather than large, multi-acre tracts.

GRAPES' $350,000 a year cost is being shared by NASA's Office of Advanced Concepts and Technology and Robert Mondavi Winery. Mondavi, which plans continued use of the technology, will make the results of the study available to other winegrowers. Other GRAPES participants, in addition to NASA and Mondavi, include California State University, Chico; the University of California — Davis; and the University of California Cooperative Extension, Napa. ●

Advanced Communications Technology

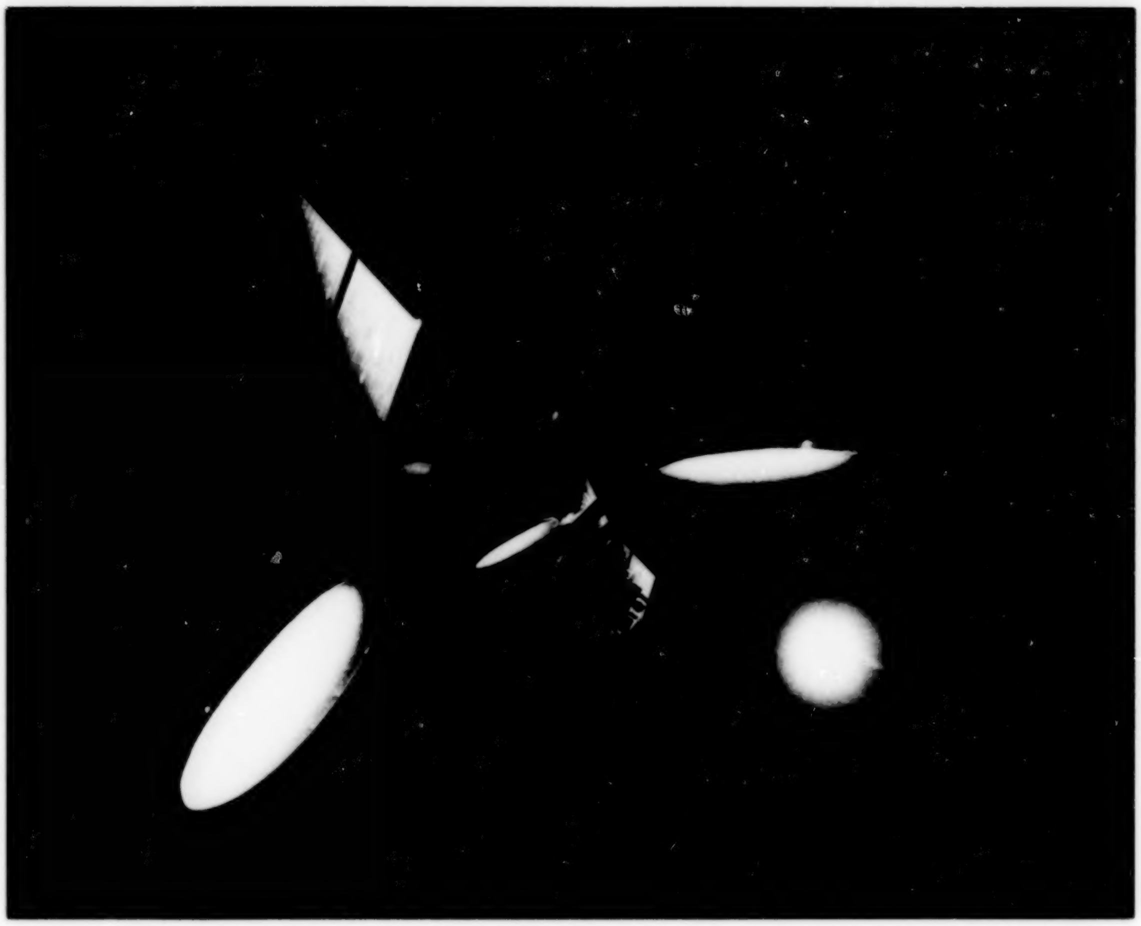
AN EXPERIMENTAL

SATELLITE TESTS

INNOVATIVE SPACE

COMMUNICATIONS

TECHNOLOGIES



Existing space communications systems evolved from high risk technology developed and flight tested by NASA in the 1960s and 1970s, exemplified by the Syncom satellites, the Applications Technology Satellite series and the Communications Technology Satellite. The technology base thus provided enabled the U.S. telecommunications industry to lead the way in developing, manufacturing and operating commercial communications satellites, with attendant benefit to the U.S. economy.

Today, as information technologies grow explosively, more advanced space communications systems are needed to meet increasing needs for new forms of communications and data transfer, and to allow more efficient use of the orbit and spectrum resources. In order to maintain the U.S. competitive position, it is necessary that NASA develop and flight test high risk satellite communications technologies that would be usable in multiple frequency bands and would be applicable to a wide range of future communications systems.

A major step toward that end is the innovative Advanced Communications Technology Satellite (ACTS). Shown ***above***, ACTS is a large satellite weighing 3,250 pounds in orbit and measuring more than 47 feet from tip to tip of its solar arrays.

ACTS will operate in the Ka-band, opening a new portion of the radio frequency spectrum where 2.5 gigahertz of spectrum is available (five times that available in lower frequency bands). ACTS also features significant capacity gain through use of multiple hopping beam antenna systems, which generate message carrying "spot beams," each focused on a narrow Earth region as opposed to the wide beams generated by existing satellites. Other advanced technologies include inboard digital processing, storage and switching of satellite signals, together with dynamic compensation for "fades" of the satellite signal due to rain or other atmospheric causes.

ACTS technologies provide

as much as three times the communications capacity for the same weight as today's satellites and are therefore more cost effective. They allow communication at much higher data rates, as much as five times that offered by existing satellites. They provide greater networking flexibility and on-demand digital services not available from current systems. Development and flight validation of ACTS technologies will allow industry to adapt the technologies to commercial requirements at minimal risk.

Additionally, ACTS technologies offer potential for lowering costs, thus making possible such new services as remote medical imaging diagnostics, global personal communications, real time TV transmission to airliners, direct transmission of image data to battlefield commanders, and interconnection of supercomputers.

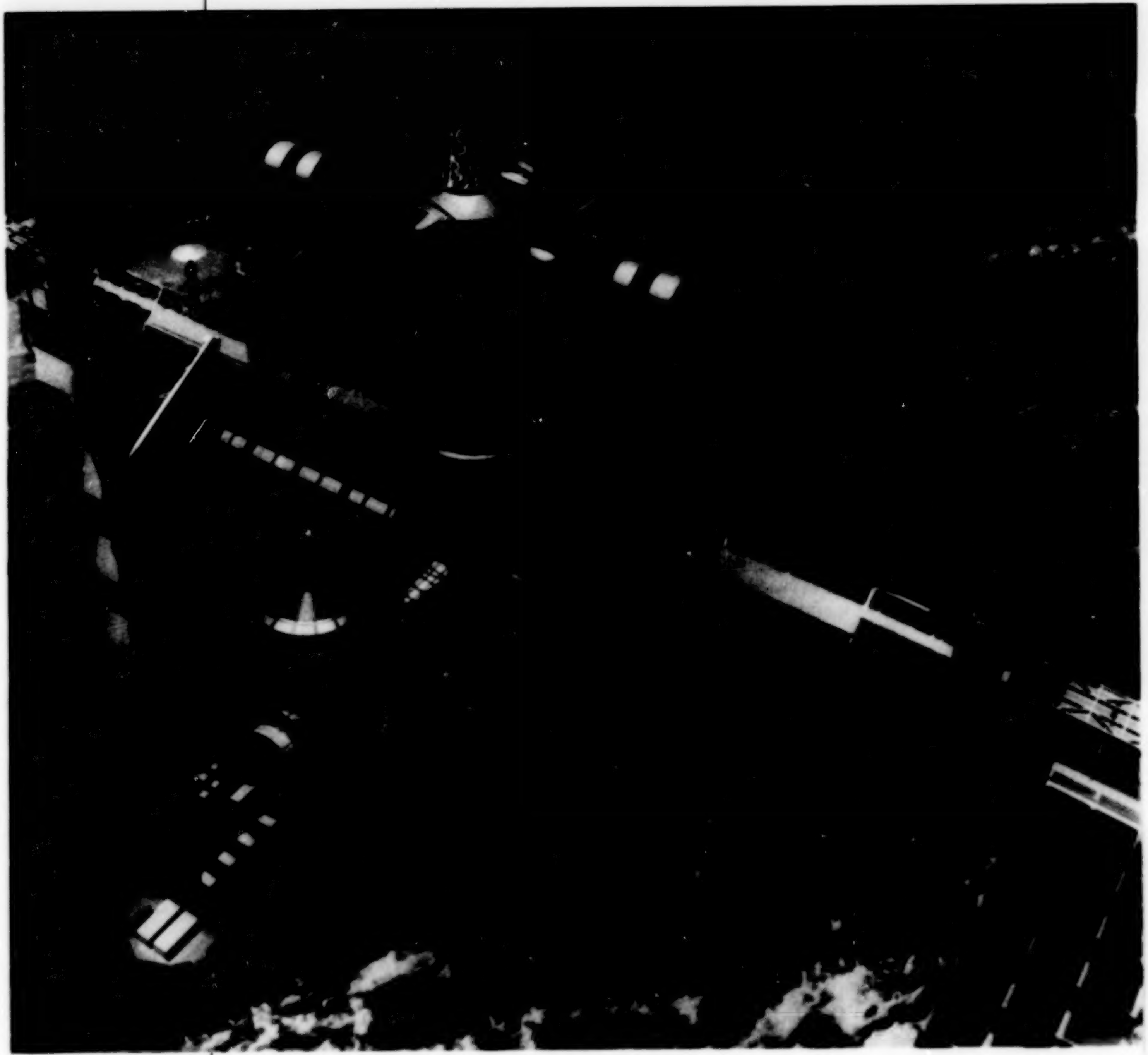
ACTS was built for NASA by Martin Marietta Astro Space (formerly GE Astro Space), East Windsor, New Jersey under the management of Lewis Research Center. The satellite is backed by an extensive ground segment with three principal types of facilities: a master ground station located at Lewis Research Center; the satellite operations center at East Windsor; and a Ka-band experimenters network consisting of a variety of Earth terminals operated by industry, universities and government organizations, with advancements that differentiate them from current terminals. The ground stations were built and equipped by Harris Corporation, Melbourne, Florida; BBN/Motorola, Chandler, Arizona; Southern California Edison Company (Irwindale); COMSAT, Clarksburg, Maryland; Virginia Polytechnic Institute (Blacksburg); Auburn University, Auburn, Alabama; and Jet Propulsion Laboratory, Pasadena, California.

A panel of industry experts analyzed how the ACTS system could most effectively employ its resources to benefit the U.S. telecommunications industry and NASA structured its ACTS Experiments Program to implement the panel's recommendations. Through the Experiments Program, researchers, doctors, scientists, educators and business professionals will be able to use ACTS to conduct investigations in such areas as medical imagery, large data base transfer, supercomputer networking and high definition television. An example is an experiment being conducted by the Mayo Foundation, Rochester, Minnesota. The foundation will test telemedicine technologies — such as interactive data, voice and video — by setting up a remote medical practice that will communicate via ACTS with a major medical center.

The overall objectives of the Experiments Program are to conduct a complete set of verification experiments to enable evaluation of ACTS technologies, and to conduct experiments/demonstrations for evaluation of potential telecommunications service applications of ACTS technologies.

A two-year Experiments Program is planned (the satellite has sufficient stationkeeping fuel for four years). Eighty-six experimenter organizations have been approved to use the ACTS system; they will conduct 73 experiments in the first two years of ACTS operations. ●

SPACE OPERATIONS



An artist's concept of the redesigned U.S./international space station, to be built in modular fashion beginning in 1998.

A REDESIGNED SPACE STATION HIGHLIGHTS MANNED SPACE FLIGHT ACTIVITY

In June 1993, President Clinton proposed to the Congress that NASA proceed with development of a new version of the U.S./International Space Station, one that offers substantial cost reductions but retains much of the capability earlier planned for the station.

The decision marked the culmination of a three-month effort, undertaken at the President's direction, to effect major economies in the program by reconfiguring the station and streamlining its management. A NASA space station redesign team developed three basic configurations with a number of sub-options within each design. A 16-member blue ribbon advisory panel, headed by Charles M. Vest, president of Massachusetts Institute of Technology, evaluated the various options and presented the White House a detailed evaluation for a Presidential decision.

The option selected by the President is essentially a scaled-down version of the space station *Freedom* design, which allows taking advantage of the investment already made in station design and hardware development. The station is to be built up in a modular fashion that provides a lower cost approach. Additional economies are expected through changes in the program management structure and operations scenario, revision of the contractor support element, work force reduction and other technical/managerial improvements.

The modified program retains the principal capability elements of the earlier station, the three pressurized laboratory modules to be provided by the United States, Japan and the European Space Agency (ESA). Although the basic configuration of the station has been determined, many of the details of the restructured program remained to be worked out at publication time; they were being resolved in coordination with the international partners and in consultation with the Congress.

Special emphasis will be placed on using existing, proven systems on the space station and on assembly and test of major components on the ground, minimizing on-orbit assembly, maintenance and checkout. The number of Space Shuttle missions required for assembly will be reduced.

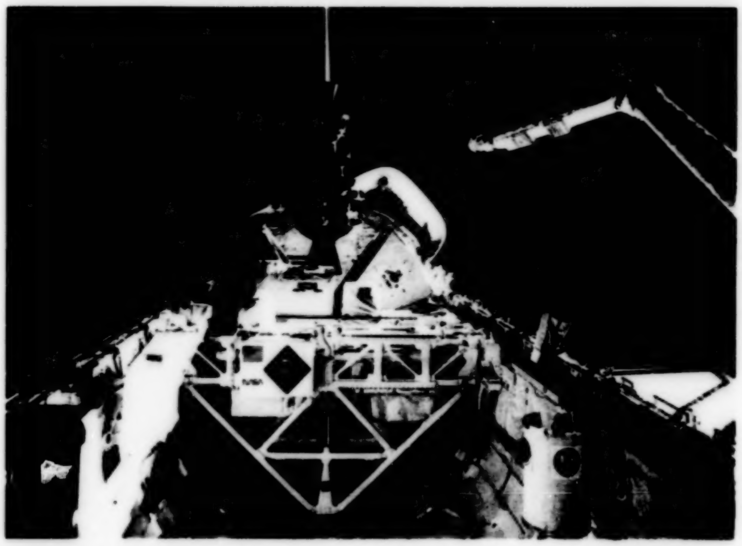
The modular build up is to be accomplished in four phases beginning in 1998.

- In Phase One, the Shuttle will deliver the central truss and solar arrays, creating a power station that would provide electricity for unmanned payloads or for an extended Space Shuttle/Spacelab mission.
- In Phase Two, the station would be expanded by the addition of the U.S. pressurized laboratory and some international equipment, creating a human-tended capability on a part-time occupancy basis.
- In Phase Three, the addition of the ESA and Japanese laboratory modules, along with other equipment, would provide an "international human-tended capability".
- In Phase Four, the station would be completed with delivery of the U.S. built habitation module and other elements, establishing a permanent human capability for a crew of four. ●

Shuttle Operations

A SATELLITE FOR EARTHQUAKE STUDIES AND AN ASTROPHYSICS OBSERVATORY ARE REPRESENTATIVE OF 1993 SPACE SHUTTLE PAYLOADS

At right is a view of the payload bay of the Space Shuttle Orbiter *Columbia* showing the LAGEOS II laser ranging geodetic satellite just before its deployment on Shuttle flight STS-52. LAGEOS II was successfully deployed on October 23, 1992, on the first Space Shuttle mission of fiscal year 1993. LAGEOS II is designed to provide information about the movement of Earth's tectonic plates and the influence of such motion on earthquakes (see page 29).



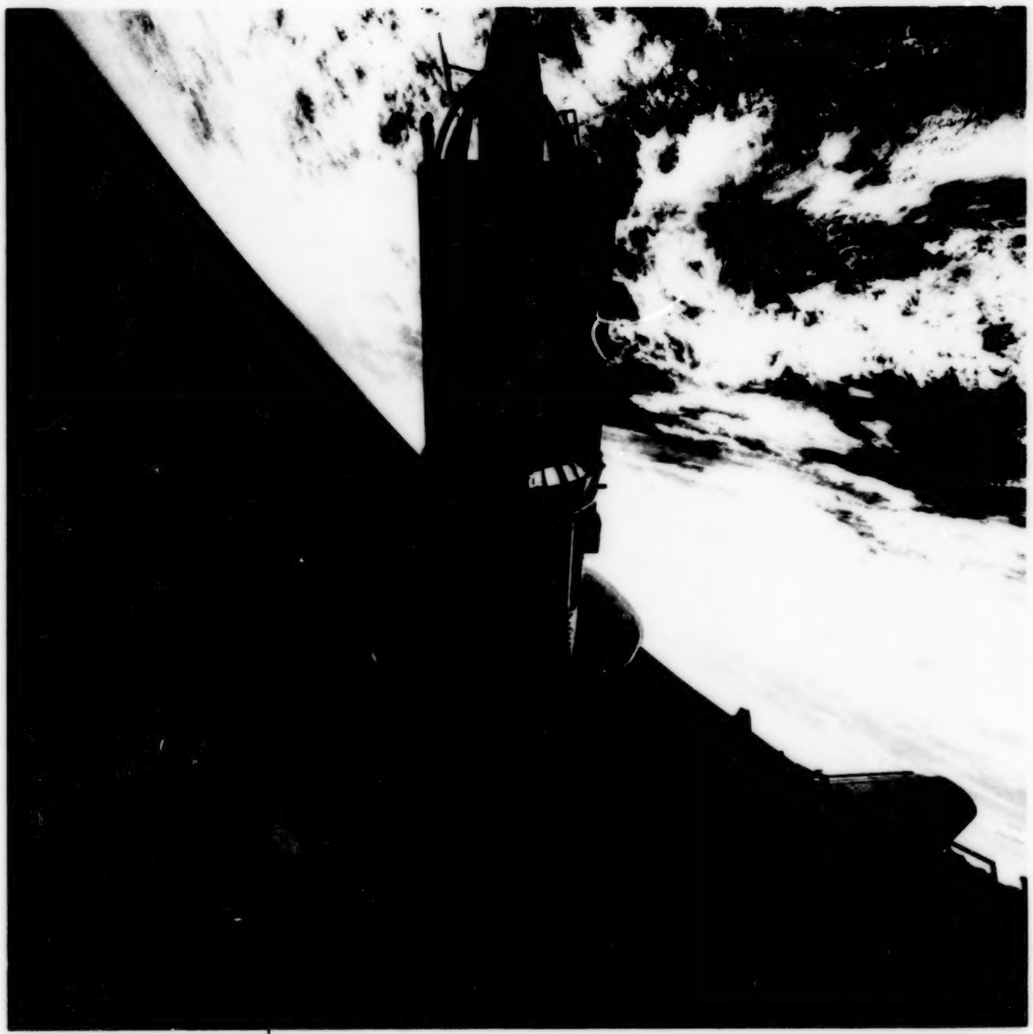
Columbia carried 10 other major payloads on STS-52, among them the first U.S. Microgravity Payload (USMP-1), which consisted of three materials processing payloads mounted on a carrier pallet. Also on board was CANEX-2, a group of Canadian experiments in robotics, coatings for spacecraft materials, materials processing and environmental science, and the European Space Agency's Attitude Sensor Package, designed to gather information on the performance and accuracy of new sensors.

STS-53, the last dedicated Department of Defense Shuttle mission, was launched on December 2, 1992. The Orbiter *Discovery* carried a classified military satellite (which was successfully deployed) along with 12 secondary experiments embracing tests of space hardware and investigations in several areas of space science. ***At left***, astronauts Guion S. Bluford (foreground) and Michael R. U. Clifford are operating a FARE experiment in the cramped quarters of the Shuttle middeck. FARE is an experiment package for investigating the dynamics of fluid transfer in microgravity to provide information toward development of ways to transfer liquids that must be replenished in long duration spacecraft, such as a space station.

Mission STS-54, Orbiter *Endeavour*, was launched on January 13, 1993, its principal payload a satellite for the Tracking and Data Relay Satellite System (TDRSS), an orbiting network that provides communications, tracking, telemetry, data acquisition and command services for Shuttle missions and for virtually all NASA spacecraft operating in low Earth orbit.

TDRS-6 and its Inertial Upper Stage (IUS) are pictured ***at right*** just before deployment from the Orbiter; the satellite was released in low Earth orbit, then boosted by the IUS to a geosynchronous orbit position at an altitude of 22,300 miles. Deployment of TDRS-6 fulfilled a NASA requirement for having two fully operational satellites and one operational ready reserve satellite in the TDRSS network; TDRS-6 became the ready reserve spacecraft, joining TDRS-4 and TDRS-5.

Another major payload aboard STS-54 was the Diffuse X-ray Spectrometer (DXS), a Shuttle-based astrophysics observatory developed by the University of Wisconsin, Madison. DXS achieved its mission objectives, measuring the faint x-rays permeating the solar system. The experiment



provided the first direct confirmation that the soft x-ray diffuse background radiation emission originates in a vast cloud of hot gas enveloping the Sun and neighboring stars; DXS data supports the theory that ancient supernovae heated electrically charged gas to produce x-rays. Scientists believe that the pocket of gas seen by DXS was created by a supernova nearly 300,000 years ago.

Also aboard STS-54, as a middeck payload, was the Commercial Generic Bioprocessing Apparatus (CGBA) sponsored by NASA's Office of Advanced Concepts and Technology and developed by BioServe Space Technologies, a NASA Center for the Commercial Development of Space. The CGBA allows performance in a single apparatus of a wide variety of biomaterial, life science and biotechnology experiments in microgravity. On STS-54, the CGBA conducted 28 separate investigations (see page 33).

On the fifth day of STS-54, mission specialists Greg Harbaugh and Mario Runco, Jr. performed the first of a series of test spacewalks to be conducted on Shuttle missions prior to the activation of the Space Station. The tests are designed to refine training methods for future extravehicular activity and expand the experience of astronauts, ground controllers and instructors. Runco and Harbaugh evaluated how well they adapted to spacewalking and tested their abilities to move about the cargo bay with and without carrying items, to climb into a foot restraint without handholds, and to align large objects in weightlessness. ***Above,*** Harbaugh (red stripe on suit) is testing his ability to carry a "bulky object" — Runco — while moving about in space. (Continued)

Shuttle Operations

(CONTINUED)

A 10-DAY, 90-EXPERIMENT GERMAN-CHARTERED FLIGHT HIGHLIGHTS SPACE SHUTTLE ACTIVITY

Mission STS-56, Orbiter *Discovery*, was launched April 8 on a science flight dedicated primarily to NASA's Mission To Planet Earth, employing the second Atmospheric Laboratory for Science and Applications (ATLAS 2) and the Space Shuttle Backscatter Ultraviolet (SSBUV) payload to gather data on the relationship between the Sun's energy output and the chemistry of Earth's middle atmosphere, and how these factors affect Earth's ozone level.

Also flying in Discovery's payload bay, along with ATLAS 2 and SSBUV, was the Spartan-201 free flying payload. Developed by Goddard Space Flight Center, Spartan is designed to study the velocity and acceleration of the solar wind and to observe aspects of the Sun's corona, information that will help improve scientists' understanding of the physics of the corona and solar wind. On the third day of the STS-56 mission, the 2,800-pound Spartan was deployed by mission specialist Ellen Ochoa, using the remote manipulator arm. Discovery was maneuvered to a position 20 nautical miles distant so that Spartan could make its measurements free of interference from the Orbiter. On the fifth day of the mission, Spartan was captured and stowed in the cargo bay.

Another experiment of the STS-56 mission was a test of a new camera called HERCULES (for Hand-held, Earth-oriented, Real-time, Cooperative, User-friendly, Location-targeting and Environmental System). The system allows an astronaut in orbit to simply point the camera at an interesting Earth feature, record the image, and let the system automatically determine the latitude and longitude of the Earth feature. This was a second check-out of HERCULES, which had been tested aboard STS-53. ***At left***, mission specialist Kenneth D. Cockrell is using the camera to acquire Earth imagery.

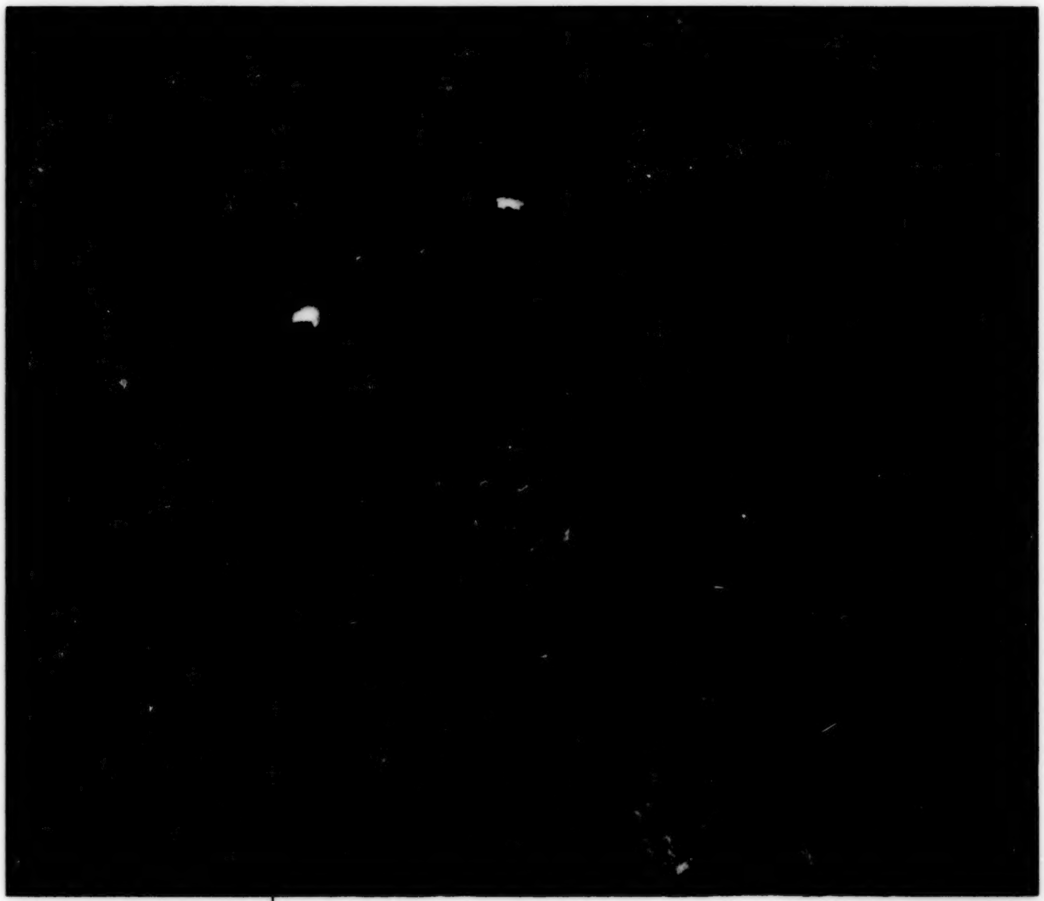
Also flown on STS-56 were repeat experiments with the Radiation Monitoring Equipment-III (RME-III) and the Cosmic Radiation Effects and Activation Monitor (CREAM). RME-III is an instrument that measures the exposure to ionizing radiation on the Space Shuttle. CREAM is an experiment designed to collect data on cosmic ray energy loss spectra, neutron fluxes and induced radioactivity. The data is collected by monitors placed at a number of locations in the Orbiter's cabin.

The unusual photo pictured ***at right*** was taken during Shuttle mission STS-56, Orbiter *Columbia*, launched on April 26, 1993. The photo captured, in one frame, a huge natural brilliance, a sheet of lightning visible in the left center portion of the photo, and the man-made brilliance of the lights of Mexico City, visible just above the top of Columbia's vertical stabilizer.

STS-55 was a mission dedicated primarily to German-sponsored experiments in the microgravity environment, conducted in the Spacelab D2 module (Spacelab D1, flown in 1985, was similarly a German-chartered program).

The mission was conducted under the management of the German Aerospace Research Establishment (DLR) with the German Space Agency (DARA) responsible for the scientific program. Payload control and operation was handled by DLR's Space Operation Control Center near Munich.

The 10-day mission was pronounced a complete success, with 100 percent of the planned experiment activity completed. Research was carried out on a round-the-clock basis with the seven-member crew divided into two



alternating teams. The crew included five American astronauts and two German mission specialists, who are shown ***at right*** working within the Spacelab module; in the foreground is Ulrich Walter and behind him Hans Schlegel.

STS-55 included some 90 experiments, sponsored mostly by Germany, but also including some provided by the European Space Agency, Japan and NASA. Most of the Spacelab D2 experiments were concerned with study of the behavior of humans and other living organisms under conditions where the force of gravity has essentially been removed.

Among the major experiments were the HOLOP (Holographical Optical Laboratory), a facility employing holography to gain insight into processes of heat and mass transfer, and of cooling in transparent materials, areas of great interest in metallurgical research; the Statolith Experiment, an investigation of the causes of space sickness involving study of the balance-sensing organs of tadpoles and the larvae of a type of perch; the Anthrorack, the most advanced medical research facility yet flown in space, in which the astronauts conducted a score of experiments ranging from investigations of body organs and their controlling mechanisms to the functions of lungs; and ROTEX, an experiment designed to gather information on how a robot operates in microgravity. (Continued)

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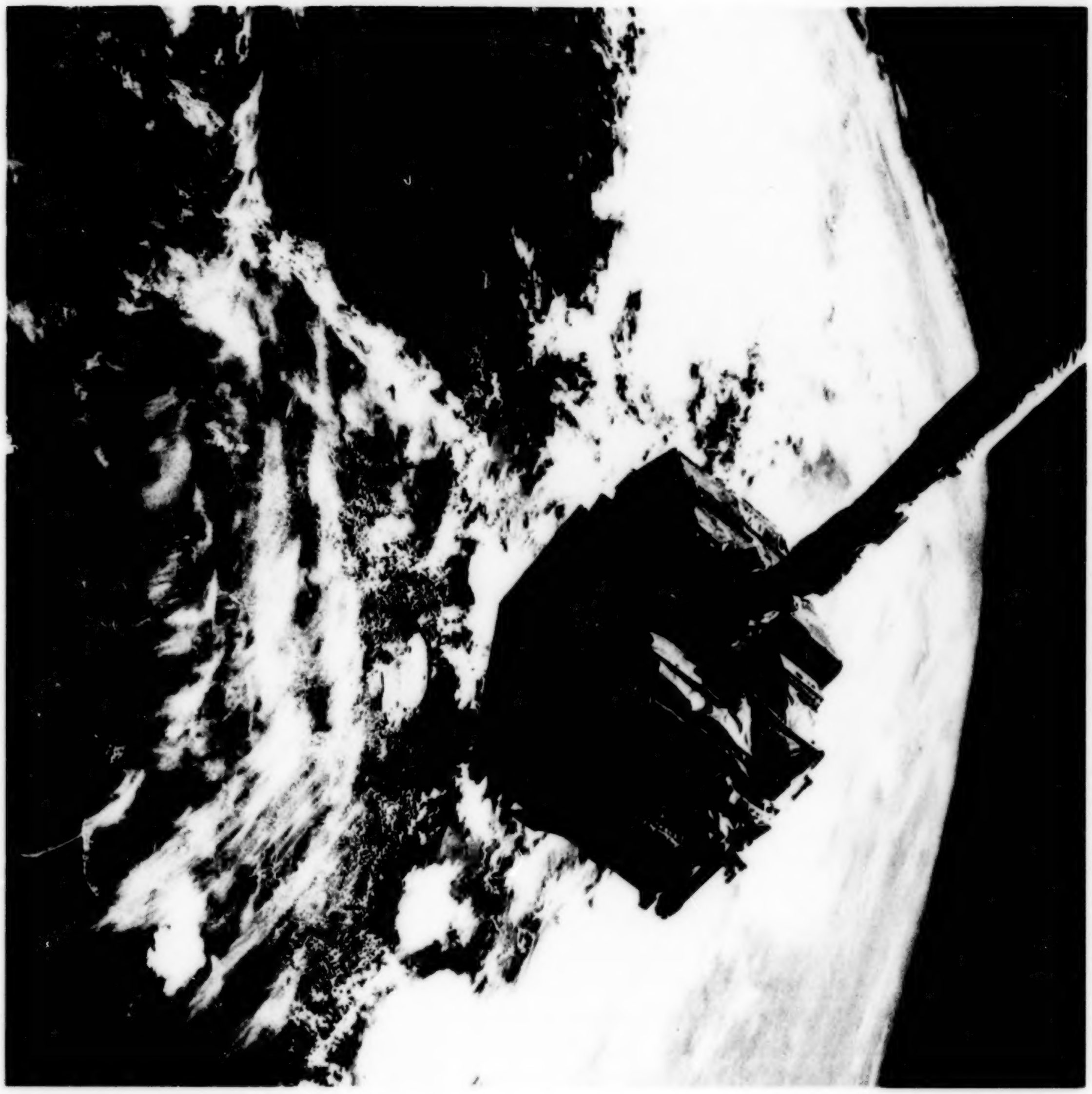
Shuttle Operations
(CONTINUED)

NASA'S COMMERCIAL SPACE CENTERS CONDUCT A BROAD RANGE OF MICROGRAVITY STUDIES IN A NEW SHUTTLE-BASED FACILITY

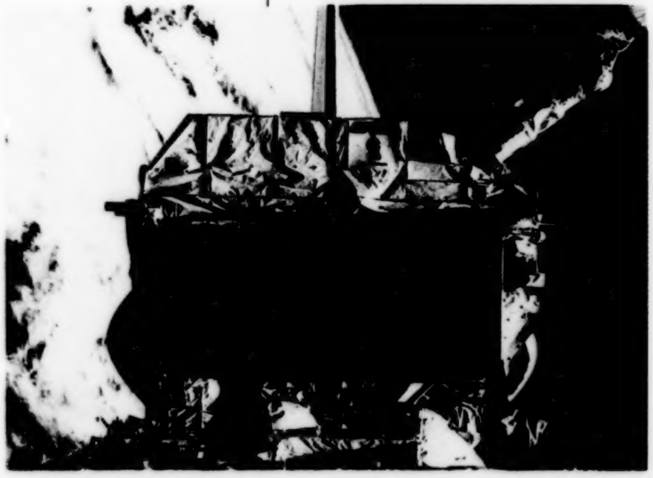


Launched June 21, 1993, STS-57, Orbiter *Endeavour*, was a very busy mission that included recapture of a free-flying payload after months in space, the debut of the SPACEHAB experiment module, a wide variety of commercially-oriented investigations, more spacewalk tests, and research by several secondary payloads.

The principal activity of STS-57 was recapture of the European Space Agency's Eureca (European Retrievable Carrier) satellite. Deposited in orbit by Shuttle mission STS-46 on July 31, 1992, the five-ton Eureca had spent 11 months as a free-flying satellite conducting research on materials science, life science, space science and radiobiology.

For three days after its launch, *Endeavour* was flown through a series of maneuvers in a "chase" of the satellite, gradually narrowing the distance between the Orbiter and Eureca. On the fourth day, a rendezvous was effected and, using the remote manipulator arm, payload commander G. David Low was able to capture Eureca (***above***) and move it into the cargo bay for stowage (***top center***).

SPACEHAB is an "augmentation module" designed to provide additional experiment rack space in a pressurized environment that enables crew tending of experiments. SPACEHAB is a privately developed system available on designated Shuttle flights for commercial experimentation. On this first flight, NASA leased virtually all of the locker space for use by the agency's Centers for the Commercial Development of Space (CCDS). It was a successful debut for SPACEHAB, which carried a broad variety of CCDS experiments ranging from drug improvement and plant feeding to high temperature melting of metals and the first soldering experiment in space by American astronauts. The CCDS experiments and details of the SPACEHAB module are covered in detail on pages 32-35.



A highlight of STS-57 was a four-hour extravehicular activity (EVA) by G. David Low and mission specialist Jeff Wisoff, a continuation of the spacewalk test series initiated on STS-54 to expand the EVA experience levels of astronauts, flight controllers and instructors in preparation for space station assembly in orbit. ***Below***, Wisoff is standing on a mobile foot restraint at the end of the remote manipulator arm. ***At right***, what looks like one upside-down astronaut hanging from the foot restraint is actually two; Low, nearest the camera, is holding the unrestrained Wisoff in a test simulating the handling of large components in space.

Among the multiple payloads aboard STS-57 was CONCAP-IV, the fourth in a series of payloads investigating the growth in microgravity of non-linear organic crystals by a novel method known as physical vapor transport. Non-linear optical materials show great promise for commercial applications.

Another STS-57 payload was SHOOT (Superfluid Helium On Orbit Transfer). The SHOOT payload was designed for development and demonstration of the technology required to resupply liquid helium containers in space. Because so little experience has been gained with handling cryogenic (very low temperature) liquids in microgravity, SHOOT was developed to gather data about how the liquid feeds to pumps, how the liquid/vapor discriminators behave, and how the liquid sloshes and cools. ●

TECHNOLOGY TWICE USED

A representative selection of new products and processes adapted from technology originally developed for NASA mainline programs, underlining the broad diversity of spinoff applications and the social/economic benefits they provide.

Spinoff developments highlighted in this publication are based on information provided by secondary users of aerospace technology, individuals and manufacturing concerns who acknowledge that aerospace technology contributed wholly or in part to development of the product or process described. Publication herein does not constitute NASA endorsement of the product or process, nor confirmation of manufacturers' performance claims related to the particular spinoff development.

NEW HELP FOR MS PATIENTS

Multiple sclerosis (MS) is a chronic, progressively disabling disease of the central nervous system that strikes men and women in the prime of life. Wasting of the nerves, caused by loss of a body substance known as myelin, can affect thought processes, vision, dexterity, balance and sensation.

A SPACE-DERIVED PERSONAL COOLING SYSTEM HEADS A SAMPLING OF SPINOFF DEVELOPMENTS IN THE FIELD OF HEALTH AND MEDICINE

Myelin normally forms a coating around the nerves like insulation around a wire. This insulation allows signals to be conducted through the nervous system; conversely, its absence bars proper functioning of the nervous system. More than 30 years ago it was discovered that body cooling can produce a dramatic improvement in MS symptoms. Experimental data shows that conduction can be temporarily restored to "demyelinated" nerves by cooling the body's core temperature only one degree Fahrenheit. Therefore, physicians have long used cold showers, pools and air conditioning to lower the body temperatures of MS patients.

Such treatment is sometimes useful but it has drawbacks. It is not practical for severely disabled patients and it can be uncomfortable. Moreover, patient immersion in a pool can sometimes be self-defeating, because body mechanisms — such as shivering and vasoconstriction (constriction of the blood vessels) — go to work to prevent a drop in core temperature.

However, many patients are now benefiting from a body cooling technique that does not require immersion, nor does it induce shivering or vasoconstriction. It involves use of a "cool suit," a device more formally known as the Mark VII MicroClimate® Medical Personal Cooling System. The suit, which consists of a head cap and a torso vest, is a spinoff from space technology developed by Life Support Systems, Inc. (LSSI), Mountain View, California. The Mark VII is being used to treat symptoms of MS and other illnesses where temperature regulation can be beneficial, such as HED (hypohidrotic ectodermal dysplasia), peripheral neuropathy, epidermolysis bullosa, spina bifida and cerebral palsy.

The Mark VII system includes a control console — either fixed or portable versions — with a cooling unit and a pump. The pump circulates a water-based fluid, cooled to about 50 degrees Fahrenheit, through "veins" or tubes in the vest and cap. Due to its efficient heat transfer, it can lower a patient's core temperature one degree Fahrenheit in 30 to 40 minutes, with sometimes dramatic improvement in symptoms that continues for two to four hours after a cooling session.

The cooling system is not a cure, nor does it help every MS patient. It has, however, helped many patients although it is still relatively new, and those for whom it works are lavish with their praise. LSSI has received a number of testimonials like this from author/journalist Charles Fox:

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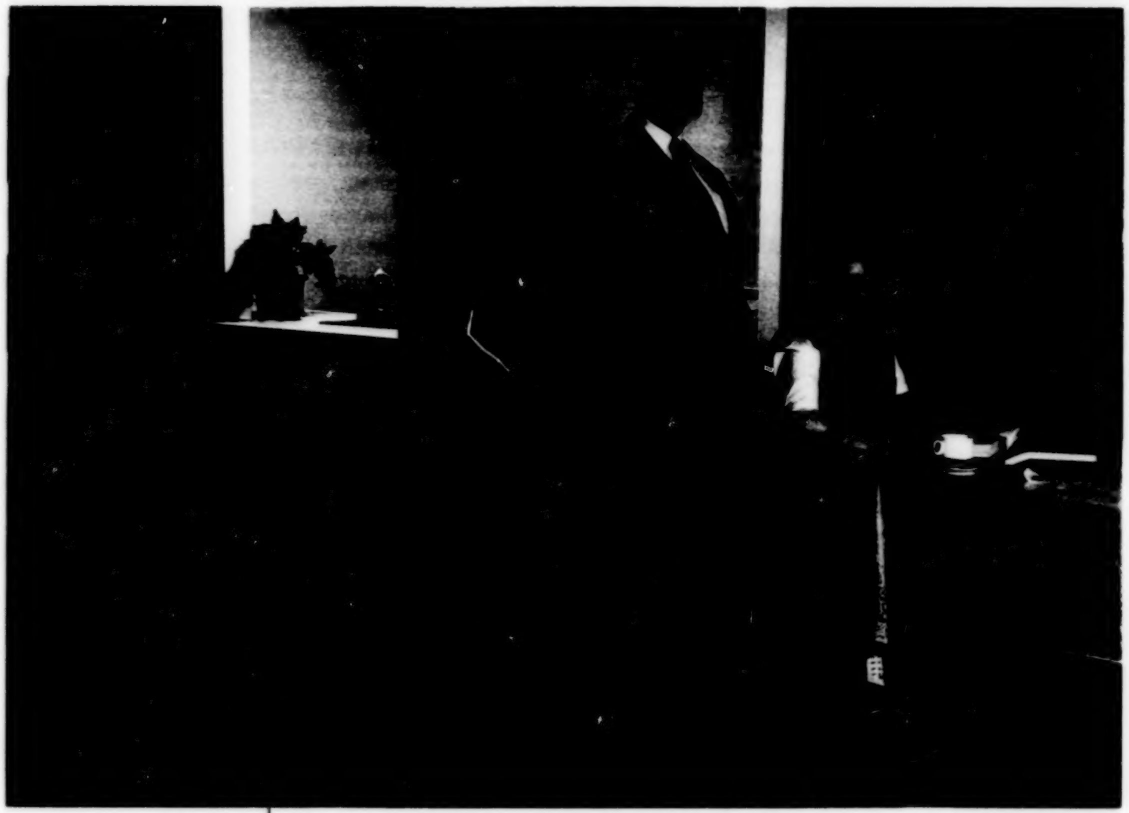

A multiple sclerosis (MS) patient at a Glassboro, New Jersey barrier-free housing facility is using a spinoff "cool suit" to lower her temperature and alleviate MS symptoms. The suit consists of a head cap, a torso vest and the cooling unit shown in the foreground. With the patient is John Hodson, Sr., founder and president of the Multiple Sclerosis Association of America, which has placed cool suits in more than 50 MS care centers in the U.S.

"It improves my speech, breathing and thinking. I have fully integrated the use of the Mark VII into my life. It's part of my life, and has brought me more relief than anything I have tried in the last twenty-three years." And this from registered nurse Sharon Giberson: "My neuropathy, speech and overwhelming fatigue improves. My depression subsides. I am blessed with a better quality of life and wouldn't want to live without it (the Mark VII)."

The Multiple Sclerosis Association of America (MSAA) has sponsored a 12-week, 12-patient detailed study of the effectiveness of the MicroClimate system; the study was conducted by Dr. Wallace Tourtellotte of the UCLA Medical Center. Final results were pending at publication time, but a preliminary report indicated that most subjects experienced reduced fatigue and improved mobility immediately after and up to three hours after cooling; four patients reported long term improvements in life quality over the six weeks in which they received daily cool suit treatments.

More MS patients will have the opportunity to see what the cool suit can do for them, since MSAA is expanding the availability of MicroClimate cooling. The association has bought and placed cool suits in more than 50 MS research care centers in the U.S. and it is estimated that, through these clinics, more than 100,000 MS patients will be able to get MicroClimate treatment. (Continued)

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* MicroClimate is a registered trademark of Life Support Systems, Inc.

NEW HELP FOR MS PATIENTS
(CONTINUED)

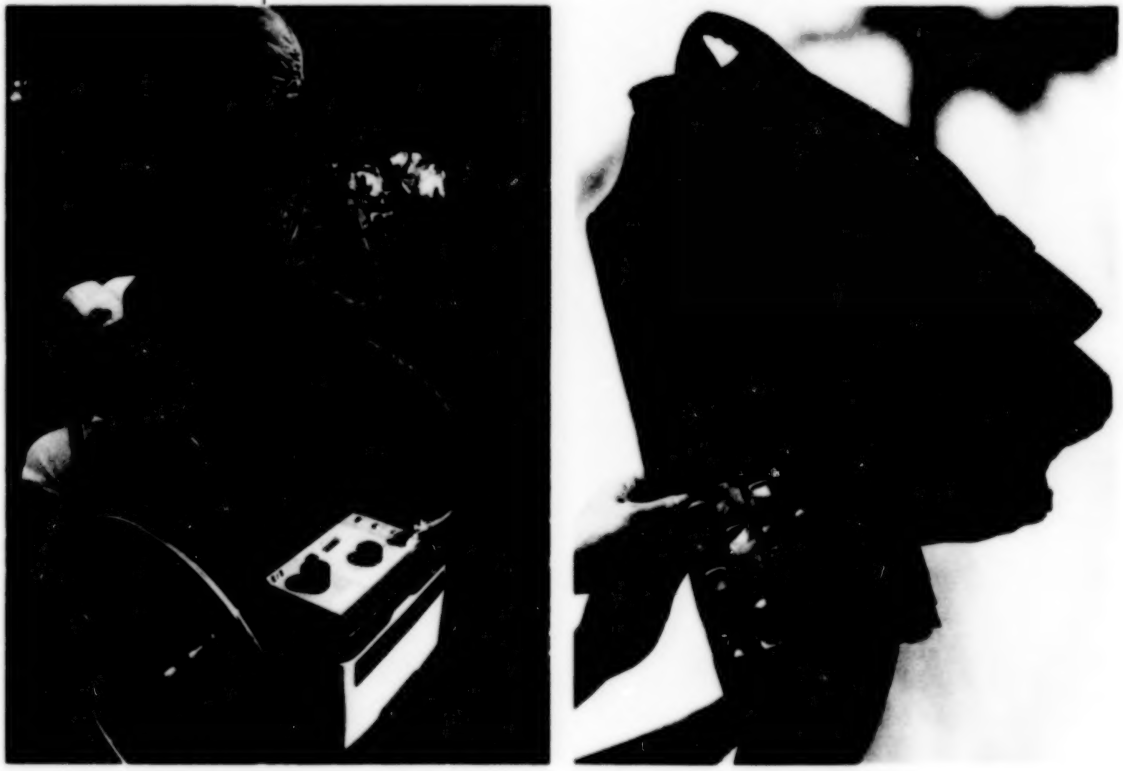
Life Support Systems, Inc. (LSSI) did not start out with the intention of producing medical systems. The medical application of the company's cooling technology sought the company. It resulted from nationwide publicity when LSSI began providing cool suits for children afflicted with HED (hypohidrotic ectodermal dysplasia), who have no natural cooling system because they were born without sweat glands. The extraordinary success that accompanied use of the LSSI Mark VII MicroClimate System for alleviating HED symptoms prompted a flood of inquiries from people in the U.S. and abroad about the LSSI cooling technology and sparked development of units especially designed for medical applications.

By that time — in the latter 1980s — LSSI was already an established company, a NASA spinoff company, in fact; its entire line of temperature regulation products stemmed from a NASA technology that the company modified and refined to produce a variety of cooling systems for military, recreational and industrial applications.

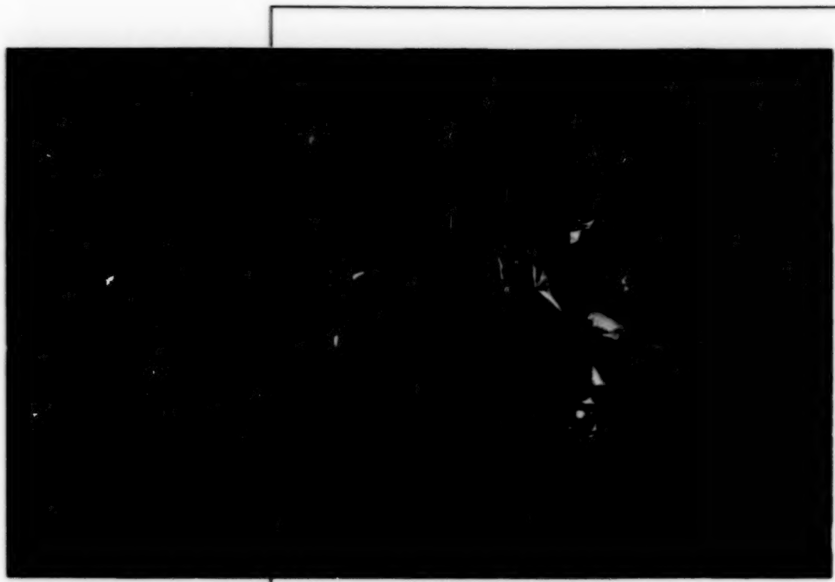
The MicroClimate technology had its origin in a 1968 NASA development program at Ames Research Center that produced a spacesuit undergarment for cooling astronauts on the surface of the moon or during extravehicular forays outside a spacecraft or space station; the system circulated a fluid, cooled by a heat exchanger and delivered by a battery-powered minipump, through a network of tubes in the garment.

In 1971, Ames awarded a contract to Acurex Corporation for an extension of the technology: a heat stress alleviating liquid-cooled helmet liner for helicopter pilots. In the mid-1970s, NASA, Acurex and the Bureau of Mines carried the technology a step further with development of a self-contained cooling system for mine rescue work.

In 1980, William Elkins, formerly with Acurex and long associated with cooling system research, founded LSSI to pursue commercial uses of the technology. In the years since, LSSI has refined the technology and brought to the commercial marketplace three generations of improvements.



The Life Support Systems, Inc. (LSSI) Mark VII cooling/control unit can be mounted on the rear platform of a patient's wheel chair; the unit feeds fluids to the cool suit through an umbilical tube. In the near photo is an alternative type of vest cooled by a quick-change ice cartridge.



Wearing an LSSI Integrated Cooling System (blue chest pack and cap), a Hazmat team member is helped into a protective vapor suit by a teammate. The chest pack includes a cooling cartridge and controls.

The company has grown into a thriving business that has expanded both horizontally — more and more applications — and vertically — increasing orders for some of the principal applications. MicroClimate cooling systems are in service with U.S. and foreign military services who must perform arduous tasks while wearing hot and bulky protective gear; for airmen flying unpressurized aircraft; for armored vehicle crews; and for shipboard personnel engaged in such heat stressful work as operations in boiler rooms or steam catapult rooms.

The range of civil applications is even broader. It includes protection for public service and industrial firefighters, plus workers in such industries as nuclear power, primary metals reduction, glass manufacturing, chemical processing, petrochemical refining, paper production, steel mills and foundries, and agricultural crop dusting.

LSSI has also moved into the sports and recreational field by providing cooling equipment for professional race car and hydroplane drivers; the list of users reads like a Who's Who of those sports.

For its importance and broad potential, LSSI's cool suit was elected to the U.S. Space Foundation's Space Technology Hall of Fame in 1993.

LSSI recently introduced a MicroClimate unit especially designed for hazardous materials handlers who must wear protective clothing for long periods. This system, along with the medical systems, represents a fourth generation of LSSI development of the original technology. The company expects to sell between 5,000 and 10,000 MicroClimate systems over the next five years — and that doesn't include the hazmat and medical systems, whose sales potential have not yet been evaluated. ●

A variation of the MS patient's cool suit is the Mark I Surgical Personal Cooling System for medical personnel who must wear protective clothing in hot operating room environments.

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Medical Research System

NASA MICROGRAVITY CELL TISSUE STUDIES LEAD TO DEVELOPMENT OF AN IMPORTANT MEDICAL RESEARCH SYSTEM

In 1992, three Johnson Space Center (JSC) researchers were named co-recipients of the 1991 NASA Inventor of the Year Award for development of a rotating bioreactor cell culture apparatus that promises extraordinary benefit to medical research. The awardees were Ray P. Schwarz, Dr. David A. Wolf, and Tinh T. Trinh. Dr. Wolf is an astronaut and space physician. Schwarz and Trinh were engineers employed by a JSC contractor at the time of the invention.

The work of the JSC trio began as a hardware development for study of the effects of microgravity on mammalian (including human) cell tissue cultures, along with a parallel investigation of a means to protect easily-damaged cell cultures during launchings and landings of the Space Shuttle. In the process of simulating zero gravity biosynthesis, the group serendipitously developed the bioreactor that makes it possible to produce many types of cell cultures that will otherwise not grow outside the human body. The invention is widely regarded as a significant advance that opens new avenues in cancer research, tissue regeneration research, and general research into the functions of cells and tissues.

To commercialize the technology, Ray P. Schwarz and his project manager, C. D. Anderson, formed Synthecon, Inc., Friendswood, Texas to manufacture and market the Rotary Cell Culture System (RCCS), a refined version of the JSC technology. NASA granted exclusive licenses to the patents and the company introduced the RCCS late in 1992. Schwarz, now chief engineer of Synthecon, is shown ***at right*** examining a component of the bioreactor. C.D. Anderson, Synthecon president, is pictured ***below right*** consulting with company chief biologist Dr. Marlene Warner.

Standard laboratory techniques for growing mammalian cells limit the size and quality of the tissues and generally produce only flat two-dimensional tissue. Tissues grown in the bioreactor are larger, three-dimensional, and they exhibit many of the structural and chemical characteristics of normal tissue. NASA scientists have seeded cultures with the same mixture of cells that normally occurs in the human body and observe their growth and development into tissue material very similar to the parent tissue.

The RCCS enables growth of human tissue, cancer tumors and virus cultures outside the human body, which may allow study of the transformation and growth of cancers continuously as they advance from single cells to tumors; ***at right*** is a magnified view of a mass of colon cancer cells grown in the RCCS. Cancer treatment clinics may also be able to use the technology to perform multiple tests of chemotherapeutic agents on a patient's own cancer *outside* of the patient's body. For AIDS research, the RCCS can produce human HIV host cells that can be infected and studied in the effort to develop an AIDS vaccine.

The components of the RCCS are shown ***at upper far right***. The system includes a tubular cylinder that is enclosed by the end caps shown in the foreground to form the cell culture chamber. The chamber is filled with a liquid medium (***bottom right***) to which tiny micron size beads have been added (mammalian cells must attach themselves to an object in order to grow and the beads provide the requisite attaching surface). The culture chamber is then rotated around a horizontal axis and the cells establish an orbit that approximates free fall through the liquid medium.

The cells are fed oxygen necessary for growth by diffusion into the chamber through a porous wall. As the cells or cell clusters grow, the speed of rotation is adjusted to compensate for the increased sedimentation rate of the denser cell masses. The RCCS has no internal moving parts, therefore minimal turbulence and "shear" forces that might damage the delicate cells. The results of several years testing, says a NASA report, show that the rotating bioreactor has proved to be "a significant tool for use on Earth in the culturing of mammalian cells" and has demonstrated that it is "at least an order of magnitude superior to the prior known technology for mammalian cell culturing."

The Mid-Continent Technology Transfer Center's Houston (Texas) Office played a supporting role in the commercialization of the RCCS. The center's primary work involved assistance to Synthecon in preparation of a strategic plan enabling the company to map out its capital needs based on growth prospects. Mid-Continent also helped Synthecon by arranging contacts with JSC, NASA Headquarters and commercial service providers, such as accounting firms and management consultants. The Mid-Continent Technology Transfer Center is one of six NASA Regional Technology Transfer Centers established in 1991 to facilitate transfer of technology from NASA and other government agencies to the private and academic sectors (see page 134). ●

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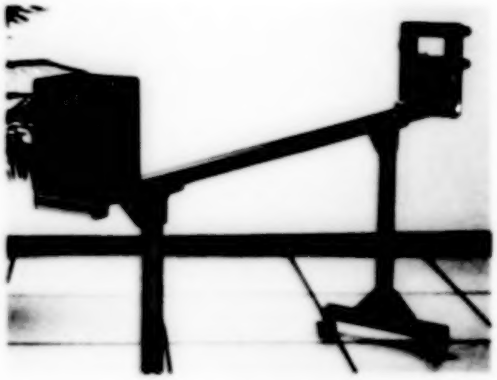
Vision Screening

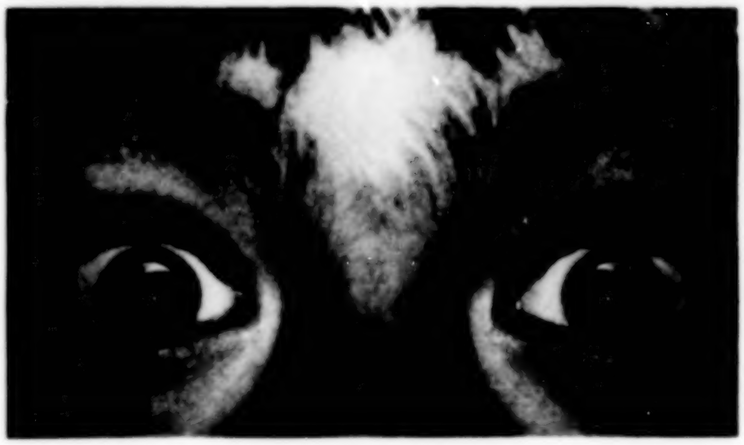
A NASA DEVELOPED EYESIGHT SCREENING SYSTEM OFFERS INSTANT DETECTION OF DEFECTS

At right is the VisiScreen* OSS-C (Ocular Screening System-Clinical), a device designed to detect eye problems in children through analysis of retinal reflexes. The system, which incorporates NASA image processing technology, was originally developed by Marshall Space Flight Center as an applications engineering project; it is now produced and marketed under an exclusive NASA license by Vision Research Corporation, Birmingham, Alabama.

The photorefractive OSS-C offers two major advantages in eye screening: it is very fast, literally as fast as taking a photo, and it requires no response from the subject, thus can be used to screen children as young as six months. OSS-C is capable of detecting a wide range of eye problems that should be treated by an eye care professional to correct or prevent progression of the defect. Vision Research's marketing is targeted toward 1) pediatricians and organizations concerned with children's eyesight and 2) corporation-sponsored mass screening services in schools and day care centers.



The OSS-C's photorefractor is basically a 35 millimeter camera with a telephoto lens and an electronic flash; the camera system is located in the black box. ***At right*** is the head positioning station six and a half feet from the camera. The flash sends light into the youngster's eyes and the light is reflected from the child's retinas back to the camera lens. The photorefractor analyzes the retinal reflexes generated by the subject's response to the flash and produces an image of the child's eyes in which the pupils are variously colored; the nature of a defect is identifiable by a trained observer's examination of the image. Example: the patterns in the pupils ***below*** can indicate—or lead to—amblyopia, or "lazy eye," the leading cause of preventable blindness in children.



Vision Research began marketing the OSS-C in mid-1991 and within a year pediatricians in 16 states were using the system. Additionally, a number of civic and school organizations acquired the system, including several that concentrate on handicapped and special-ed children; these children are typically difficult to screen by any other method and they show a much higher percentage of eye problems than the normal population. In 1992, about 50,000 children were screened by the OSS-C and some 4,000 of them showed problems significant enough to warrant professional attention. ●

* VisiScreen is a registered trademark of Vision Research Corporation.

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Heart Imaging System

ASTRONAUT MONITORING TECHNOLOGY IS USED IN AN ADVANCED HEART IMAGING SYSTEM

Below, a heart patient rides an exercise bicycle to increase cardiac function while a medical technician uses a special camera to make images of the heart. The camera is an advanced technology MultiWire Gamma Camera (MWGC) used in nuclear medicine to image heart conditions six times faster than conventional devices.

The MWGC is marketed by Xenos Medical Systems, Houston, Texas. One of the key elements of the system, a generator for the radioactive source injected into the patient, is supplied to Xenos by Proportional Technologies Inc., Houston, Texas, a company formed by Dr. Jeffrey L. Lacy (***right***), assistant professor of medicine at Baylor College of Medicine, Houston, to develop a commercially viable process that would enable use of the new radiopharmaceutical Tantalum-178 (Ta-178) in the camera system. The camera is based on technology developed by Dr. Lacy when he was a NASA biomedical researcher at Johnson Space Center (JSC); the commercial product evolved from technology that originated in a JSC project for a device to test astronauts' heart function in microgravity. Both the camera and the generator developments were partially funded by NASA.

The camera offers a number of features that distinguish it from conventional nuclear medicine cameras, including portability, high resolution and exceptional imaging speed. Most important is the use of Ta-178 as the radioactive source; Ta-178 can only be optimally imaged with the MWGC. Because Ta-178 is an extremely short-lived isotope, the body is subjected to it for a brief nine-minute period, where other commonly used substances remain in the body for six to 72 hours. Thus the radiation dose is reduced 20 to 200 times and the technique can be used more frequently on adults. Ta-178 also permits use of the MWGC on pediatric patients, who are rarely studied with conventional isotopes because of the high radiation dosage. The MultiWire Gamma Camera is being marketed in Europe and the U.S. ●

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Bladder Monitor

NASA ULTRASOUND TECHNOLOGY ENABLED DEVELOPMENT OF A NEEDED BLADDER SENSING DEVICE

Loss of the sensation of bladder fullness is a common clinical problem often seen in patients suffering from spinal cord injury, stroke aftermath and diabetes mellitus; additionally, a lack of understanding of the sensation is found in some mentally retarded people. The problem is often accompanied by urinary incontinence, which is not only lifestyle-limiting but can be a serious health problem when retention causes urine backup into the kidneys and induces infection.

The need for a compact, easy-to-use, bladder fullness sensing device led to a collaborative development effort between Langley Research Center and The Arc (formerly the Association for Retarded Citizens), with assistance from the NASA Technology Applications Team, Research Triangle Institute, North Carolina. The multiyear effort, supported by the National Institute of Disability and Rehabilitation Research, focused on use of Langley's advanced ultrasonics technology to produce a method of sensing bladder volume.

The collaboration resulted in successful test of a prototype system in 1989 and NASA and The Arc concluded an agreement assigning to the organization the licensing rights for medical applications. The Arc sublicensed the rights to Diagnostic Ultrasound Corporation (DxU), Kirkland, Washington, which conducted additional research and combined the NASA technology with its own technology for commercial marketing.

Above, a model displays DxU's BladderScan™ Monitor, which continuously records and monitors bladder fullness and alerts the wearer or caretaker when voiding is required. Shown in closeup ***below***, the sensor is no longer than a deck of cards; it is held against the lower abdomen by a belt and connected to the monitor by a short flexible cable. The sensor obtains bladder volume data from sound waves reflecting off the bladder wall.

The monitor can be worn externally with a shoulder strap or concealed beneath the wearer's clothing. The patient records void history by touching appropriate color-coded buttons to report time and amount of void plus the patient's ability to predict onset; the monitor provides a printout for the physician or caregiver. Central monitoring systems are planned for use in long term care settings, so nurses can intervene on a timely basis to assist with individual toileting needs. ●

™ BladderScan is a trademark of Diagnostic Ultrasound Corporation.

Light Visor

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SPACE TECHNOLOGY CONTRIBUTES TO A NEW LIGHT THERAPY DEVICE

Seasonal Affective Disorder, or SAD, is a form of depression recognized by the American Psychiatric Association. Brought on by the reduced light and heightened gloom of winter, it is evidenced by such symptoms as depression, a nagging need for rest even after 10-12 hours sleep, weight gain, a craving for carbohydrates, decreased sex drive, and an inclination toward social withdrawal.

Some 25 million Americans suffer from a mild form of SAD commonly dismissed as "winter blues." But for 10 million others, it is more serious; clinical depression and other manifestations of SAD become so severe that these people cannot function normally in winter.

In recent years, medical researchers have found that this affliction can be successfully treated with light therapy — use of properly timed exposure to light to change the flow of various chemicals in the body and thus improve mood and performance. NASA has conducted research in light therapy and now employs it regularly as a means of helping astronauts adjust their internal rhythms during orbital flight. Light therapy also has potential for alleviating jet lag among airline crews and passengers, for keeping military aviators alert on long missions, and for resolving health and performance problems associated with shiftwork.

Dr. George C. Brainard, associate professor of neurology at Jefferson Medical College, Philadelphia, Pennsylvania, has been engaged in light therapy research as a NASA consultant and independently as head of a Jefferson team engaged in development and evaluation of a portable light therapy device that bathes the eyes with bright light to combat SAD. ***Above***, Dr. Brainard is adjusting a Light Visor™, a sort of topless hat fitted with small incandescent lights manufactured by Bio-Brite, Inc., Bethesda, Maryland. The Light Visor allows continuous light therapy without the inconvenience of spending hours at a time before a stationary light box. The light is normally battery powered, but there is a plug-in option for home use.

Dr. Brainard is a co-inventor of the head-mounted device, along with Dr. Norman E. Rosenthal and Dr. Thomas Wehr, both research psychiatrists with the National Institute of Mental Health (NIMH). The commercial version of the Light Visor pictured is a refined, third generation device, developed in a collaboration among Bio-Brite, NIMH and Jefferson Medical College that included three years of clinical testing at these and other medical institutions. Dr. Brainard continues to conduct research on various aspects of light therapy, including its applicability to jet lag, shiftwork-related disorders and lighting design for spacecraft interiors. ●

™ Light Visor is a trademark of Bio-Brite, Inc.

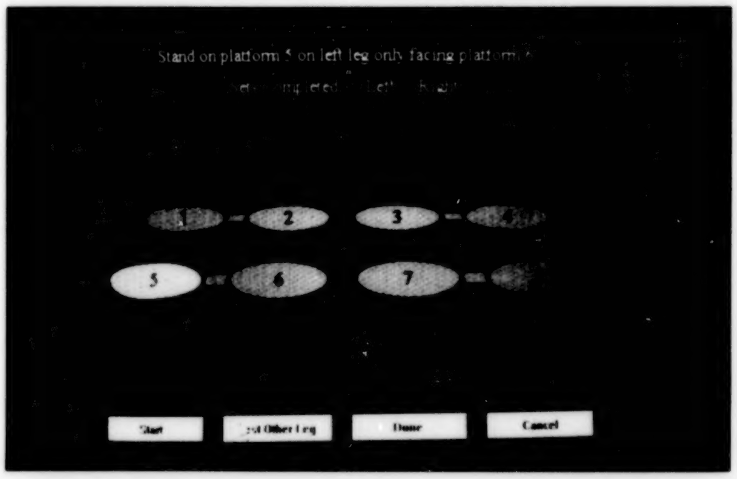
Rehabilitation Tool

A MOVEMENT THERAPY DEVICE IS BASED ON SPACE SENSOR TECHNOLOGY

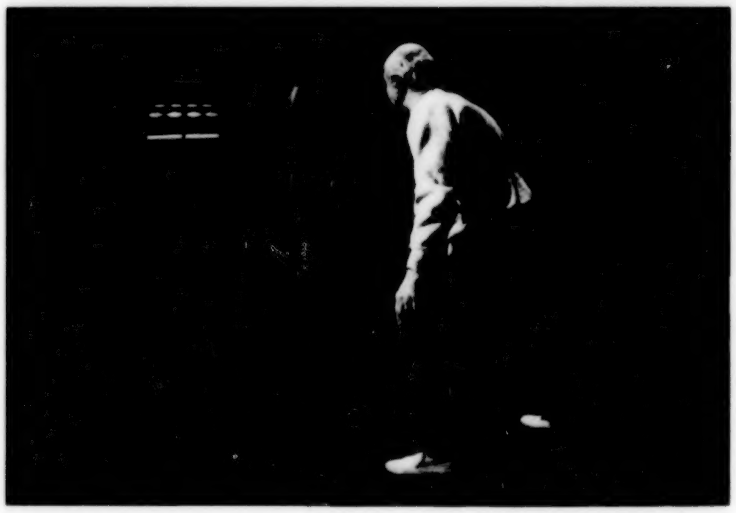
In the mid-1980s, martial arts expert Barry French developed a technique for measuring precisely the force of a karate kick or a boxer's punch and introduced to the market the Impax line of force measurement products, which are produced and sold by a company French formed, Impulse Sports Training Systems, Inc., Rocky River, Ohio. Impax products incorporate a piezoelectric film sensor similar to NASA-developed sensors that measure microscopic particle impacts in space. French's developments benefited from technical assistance provided by Lewis Research Center on such matters as sensors, materials and optimal structures.

Building on those technologies and again benefiting from NASA assistance, French has formed Impulse Technology, Inc. to develop and bring to the marketplace a new force sensing system known as Biotran™. It is intended primarily to help physicians and physical therapists treat people with movement deficiencies, although it also has applications in sports training and evaluation.

A person's ability to initiate and coordinate weight-bearing movement may be compromised by injury, disease or any type of dysfunction that affects strength, balance, agility, or joint stability. Biotran serves as a post-injury or post-surgery tool of rehabilitative medicine. It provides a means of testing weight-bearing capabilities through direct measurement, but it does more than simply evaluate; it actively assists in the rehabilitation process, putting patients through a course of computer-directed exercises designed to improve strength and balance reaction time.

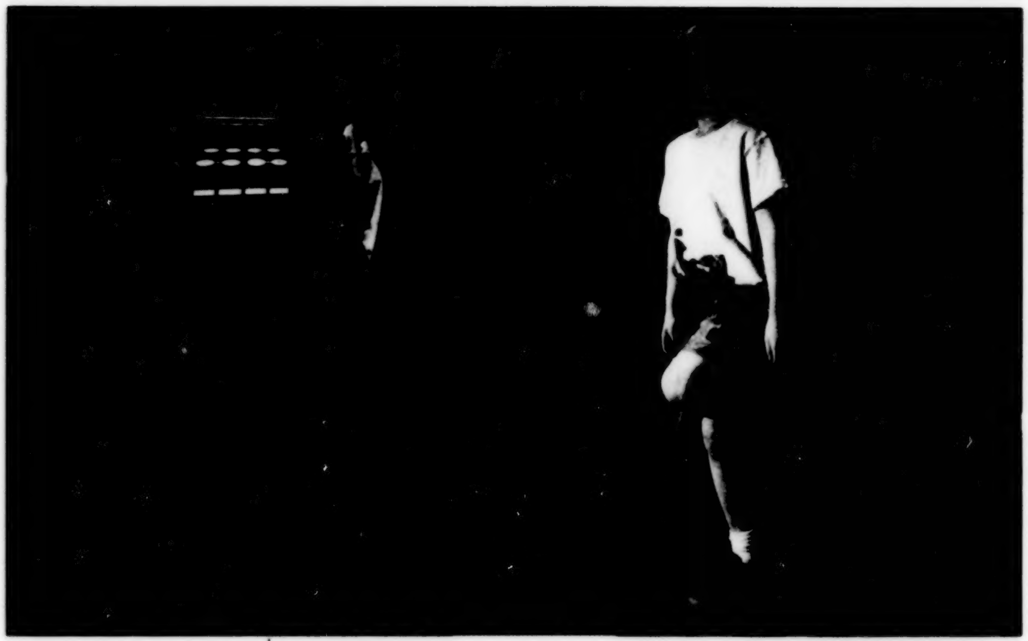


"Stand on platform 5 on left leg only facing platform 6"



Biotran has been called an "intelligent floor." It is basically a set of 7-19 floor-based force sensing platforms linked to a personal computer. A color monitor cues the user through a series of exercises in a sort of interactive video game. It may, for example (as shown ***at left***), direct the user to "Stand on Platform 5 on left leg only facing Platform 6," then follow with a rapid series of instructions to follow a sequence of hops and steps to various platforms. As the user complies, the transducer platforms measure the impact force of his/her foot as it strikes the platform and the computer calculates such factors as reaction time, acceleration, deceleration, braking and foot speed.

At left, a user is watching the screen for instructions as he plays a kind of computer-directed hopscotch, jumping from one platform to another as advised. ***At right top*** is a simulated weight-bearing test in which the user has been direct-



ed to hop in a straight line across a row of platforms on an affected limb; a base line test of the same moves on the unaffected limb provides a comparison. In these photos, the users are working with the smaller of three Biotran models; it has seven sensing platforms in a floor area measuring six by eight feet, along with a 26-inch monitor, a data acquisition module and the requisite software. A larger model has 19 platforms and a 10-foot screen, together with the module and software.

In rehabilitative medicine, Biotran identifies and quantifies a patient's functional weaknesses or limitations, then becomes the focal equipment of an exercise/training program designed to strengthen the patient's affected parts. The system provides a means of testing and documenting progress until maximal medical improvement is achieved.

The biggest technical challenge in developing Biotran, according to Barry French, was designing the deformable sensing platform. He credits NASA with a major assist, particularly in the matter of material selection. Impulse Technology wanted a low-cost, durable material that would conform to any type of floor, and, after consulting NASA technology transfer experts, selected a custom urethane. The ***lower left photo*** symbolizes the NASA/Impulse Technology collaboration in material investigations. A portion of the sensing platform is seen at the top of the picture; the band running around the perimeter of the disc is the piezoelectric sensing film. More than 500 different types of foam, plastic and rubber compositions were tested before the ultimate selection was made, and many different ways of attaching the sensor band to the platform were tried. The combination pictured is sensitive enough to measure the heartbeat of an adult standing barefoot through the soles of the feet. ●

™ Biotran is a trademark of Impulse Technology, Inc.

ORIGINAL PAGE
COLOR PHOTOGRAPH

FINDING THE LOST CITY

Ubar was a fabled city of ancient Arabia, the hub of a lucrative trade in frankincense, an aromatic resin as valuable as gold because it was used throughout the world of 5,000 years ago for embalming, perfumes and medicines. Grown in the Qara mountains of what is now southern Oman, the frankincense was hauled by camel caravan to Alexandria and Jerusalem and Damascus, thence to the civilizations of the western Mediterranean. Trade made the merchants of Ubar fabulously wealthy and the oasis town grew into a fortress city of fame, often mentioned in Arabian literature. Then, legend has it, Allah destroyed the city because its people had become wicked.

THE USE OF SPACE TECHNOLOGY IN THE REDISCOVERY OF AN ARABIAN METROPOLIS LOST FOR CENTURIES LEADS TECHNOLOGY TRANSFERS IN RESOURCES MANAGEMENT/ ENVIRONMENTAL CONTROL

For centuries, Ubar was lost to human view. Many sought to rediscover the "Atlantis of the Sands," as it was called by T. E. Lawrence, whose planned expedition to find Ubar was interrupted by his untimely death. There were several other Ubar quests in the 20th century, but it remained for a pair of amateur archeologists from Los Angeles to spark a successful search. They had a big advantage over their predecessors: they enlisted the aid of NASA's Jet Propulsion Laboratory (JPL), the originator and world leader in space digital imaging technology. Space imaging ultimately proved to be the key to finding what its discoverers believe to be Ubar.

The quest for Ubar began a decade ago with Nicholas Clapp, a Los Angeles filmmaker and archeology enthusiast, who spent years culling information about the lost city from extensive research in ancient literature, records and maps drawn more than 20 centuries ago. From years of effort, he acquired a general idea of where to look for Ubar — but it was very general.

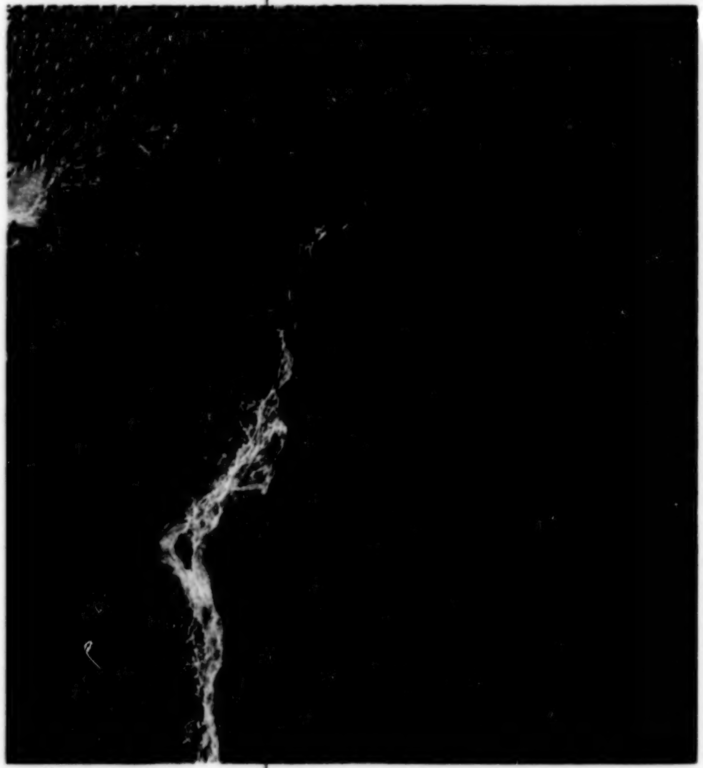
The principals of the expedition to find the lost city of Ubar: second from left, co-leader Nicholas Clapp; third from right, co-leader Sir Ranulph Fiennes; at far right, chief archeologist Dr. Juris Zarins; second from right, NASA imagery specialist Dr. Charles Elachi; center foreground, wearing hat, Dr. Ronald Blom, NASA geologist/imagery specialist.

Then he learned of NASA experiments in applying orbital remote sensing techniques to archeology, enabling detection of surface and subsurface features not otherwise detectable. He was able to obtain approval for JPL's participation in the search for Ubar.

With the help of George R. Hedges, a Los Angeles lawyer with a background in archeology, Clapp began assembling a team of experts in several fields, including three JPL space imaging specialists: Dr. Charles Elachi, Dr. Ronald G. Blom and Dr. Robert E. Crippen. Dr. Juris Zarins of Southwest

Missouri State University became chief archeologist. British explorer Sir Ranulph Fiennes was recruited as team co-leader, and he helped arrange financing for the expedition among Omani, American and British backers.

The JPL trio embarked on a multiyear effort that involved analysis of dozens of space images acquired by space sensors flying over the general area identified by Clapp — a portion of the Rub' al Khali, or Empty Quarter, the vast, almost waterless, life-hostile desert of the Arabian peninsula. They sifted through data obtained by NASA's Shuttle Imaging Radar, whose probing beams are able to penetrate beneath the desert floor and search for sand-covered structures or water. They analyzed images from the U.S. Landsat and French SPOT Earth survey satellites, whose sensors record terrain features in both visible light and in wavelengths not visible to the human eye. Because the space instruments gather data in digital form, it is possible to manipulate the data and computer-enhance the images, thereby bringing out features that ground explorers would not see.



The picture that pointed the way to Ubar, an enhanced Landsat image showing, at upper left, the sand dunes of the Rub' al Khali (Empty Quarter), and, near center photo by the dry river bed, the village of Ash Shisr, the probable site of ancient Ubar. The clearly visible light colored tracks are modern gravel roads that form a triangle around Ash Shisr. Keen-eyed analysts spotted the barely visible discontinuous and very old tracks converging on the village, suggesting it was once Ubar.

Their exhaustive analysis failed to turn up underground structures, but it did provide a wealth of caravan tracks, some of them clearly ancient because they disappeared for a time under sand dunes, then reappeared. From water availability and other data, they were able to rule out several possible sites for Ubar and direct exploration by ground teams. The analysts prepared a map of the caravan trails and noted that they converged at a place known as Ash Shisr, near the eastern edge of the Rub' al Khali. Using another space technology — satellite navigation — Dr. Zarins and his ground team found their way to a water well at Ash Shisr and began excavating.

That was late in 1991. Several weeks later, Dr. Zarins announced that the expedition had indeed found structures and artifacts that evidenced the former existence of a splendid city, one that predates any known Arabian peninsula civilization by a thousand years.

The excavators had uncovered the remains of a large octagonal fort with thick walls 10 feet high and eight tall towers at the corners, along with the ruins of a number of buildings inside the fort around the water well. In addition, they had found pieces of Roman, Greek and Syrian pottery, some of it dating back more than 4,000 years.

It may take a long time to validate that the discovery is Ubar, because the fortress was almost totally destroyed. It appears that the city was inadvertently built atop a vast limestone cave that —probably around AD300 — collapsed and brought the city's structures down into a giant sinkhole. It will take years of cautious and sophisticated excavation to probe the site without further damage. But whatever the probers find, it is clear that the expedition scored a monumental archeological triumph and added a new link in the effort to trace the spread of civilization from its origins in Mesopotamia. ●

Resources Management System

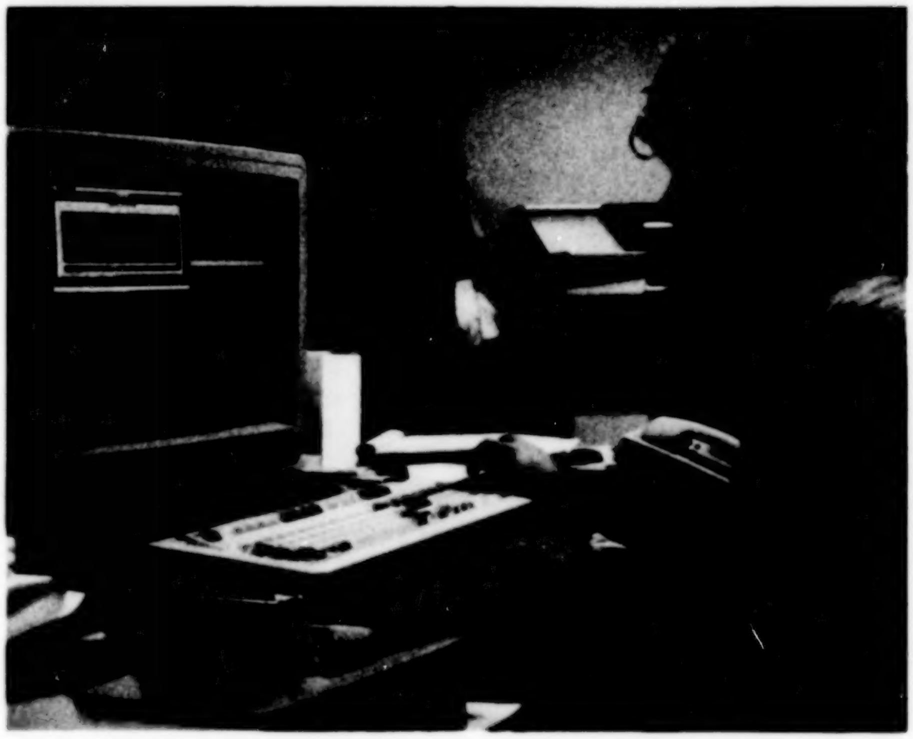
A NEW LINE OF SOFTWARE PRODUCTS EVOLVES FROM A NASA COMPUTER PROGRAM

Delta Data Systems, Inc. (DDS), Picayune, Mississippi is a "double-barreled" spinoff company, one formed by a group of former NASA/ industry engineers to produce a line of products that evolved from a NASA-developed computer program for processing remotely sensed data.

DDS initially used NASA's ELAS (Earth Resources Laboratory Applications Software) as a "shell" for developing the company's Atlas Remote Sensing and Information System, used to process satellite and aircraft data, to digitize soil and topographic maps, and to generate land-use maps. DDS has built on that experience, using ELAS as the algorithmic basis for a number of product advances in the remote sensing/ GIS market.

A recent example is AGIS, a hardware/software package designed for geographic information systems (GIS) and land information systems (LIS). AGIS (Advanced Geographic Information System) offers the capability for simultaneous processing of remotely sensed data (raster) and map data (vector). The system permits operation in raster only, vector only, or raster/vector modes; ***below***, DDS employee Deron Risinger is conducting an image analysis on a UNIX workstation with raster/vector simultaneous processing.

The AGIS software was designed to operate on a low cost microcomputer, states DDS sales literature, which adds that "AGIS provides a powerful set of resource management tools that puts GIS/LIS within reach of small and medium-sized operators." ●



Ocean Observation Instrument

For development of imaging satellites, NASA employs aircraft-based multispectral imagers to simulate the characteristics of a next-generation satellite's advanced instruments; flight testing enables developers to assess the capabilities of their instruments and make design changes early if they are required. One such program involved use of an Airborne Ocean Color Imager (AOCI) as a simulator for an advanced oceanographic satellite instrument.

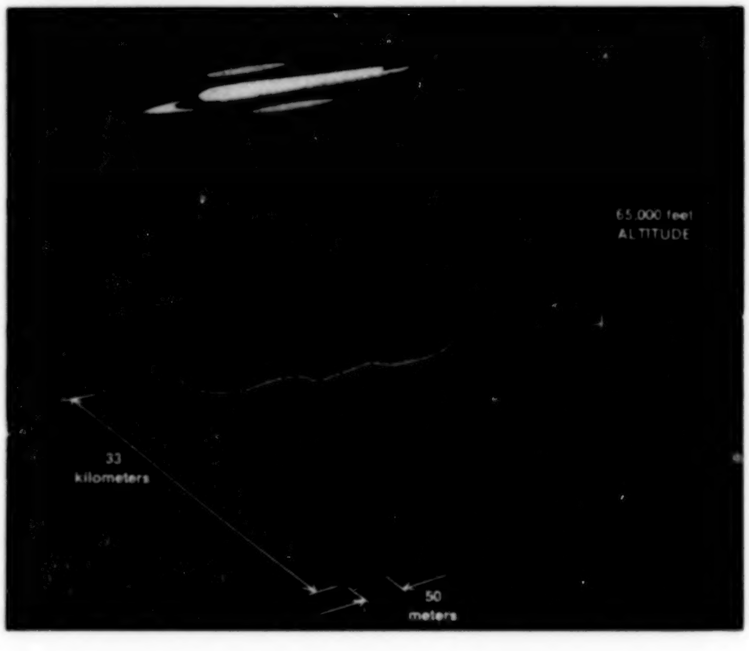
The AOCI (***above***) was developed under a NASA Small Business Innovation Research contract by Daedalus Enterprises, Inc., Ann Arbor, Michigan in the mid-1980s. The AOCI measures water temperature and detects water color in nine wavelengths. Water color is an indication of the water's chlorophyll content, or the presence of phytoplankton. In 1986, the prototype AOCI was delivered to Ames Research Center and used for flight investigations over ocean, coastal and freshwater sites, compiling data for scientists studying the effects of changing coastal landscapes on phytoplankton production.

Since there is a distinct correlation between chlorophyll content and fish concentration, AOCI had obvious commercial potential as a real-time means of providing fishing fleets information about fish locations. A commercialization effort was begun in 1988 under the auspices of NASA's Earth Observations Commercial Applications Program. The project was co-funded by NASA, Daedalus, National Marine Fisheries Services, Zapata Haynie Corporation, Hammond, Louisiana, one of the largest U.S. commercial fishing companies, and SpectroScan Inc., Coral Gables, Florida. The latter company planned to use AOCI to offer airborne multispectral remote sensing services on a commercial basis.

The commercialization program included a number of technical improvements to the AOCI, development of new data processing procedures to permit near-real-time processing, and new data dissemination techniques to get the information to fishermen on a timely basis. A series of demonstration flights was conducted in 1990/91 over the Gulf of Mexico (the drawing ***below*** illustrates the type of coverage provided by the AOCI mounted in the high altitude aircraft used for the tests). The tests demonstrated conclusively that AOCI could provide beneficial assistance to commercial fishing operations.

AOCI was successfully commercialized in 1992 with delivery of the first unit to an Italian company. Daedalus Enterprises continues to market the system worldwide in two versions, one for commercial fishing uses and one for oceanographic research conducted primarily by government agencies. ●

A BOON TO COMMERCIAL FISHING FLEETS EMERGED FROM NASA DEVELOPMENT OF A RESEARCH INSTRUMENT



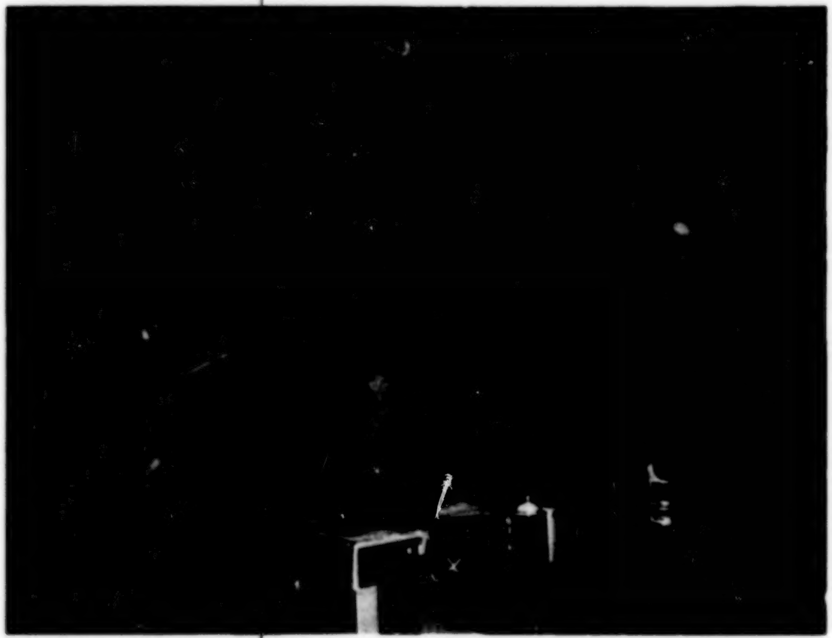
Natural Air Purifier

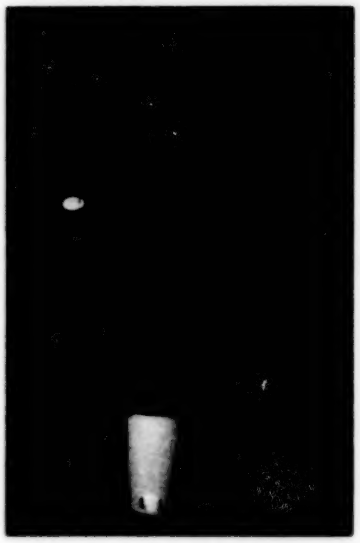
AN OFFSHOT OF NASA ENVIRONMENTAL RESEARCH IS A PLANT-BASED AIR FILTERING SYSTEM

Below, Bryan James, owner of Anchor Printing, Baytown, Texas, displays a BioFilter 2000 natural air purifier, one of several he uses to remove fumes from his print shop. BioFilter 2000, disguised as an attractive planter, is described as a "living machine;" it employs a biological filtering system to reduce or eliminate odors and pollutants in indoor air. The technology was developed by Dr. Billy C. Wolverton and his associates at the Environmental Research Laboratory of John C. Stennis Space Center, Mississippi as part of a 20-year research program aimed at eventual development of a bioregenerative life support system for long duration spacecraft.

The BioFilter 2000 is the initial product of Terra Firma Environmental, Baytown, Texas, a Native American-owned company founded by president Federico T. Marques, who is pictured ***at right*** with a sampling of his products. Wolverton, now retired from NASA and operating Wolverton Environmental Services, Inc., Picayune, Mississippi, served as a consultant to Terra Firma. The filter system is designed to combat "sick building syndrome," an acute incidence of indoor air pollution that can occur in highly insulated or poorly ventilated offices and residences; it can cause burning throat, nose and eyes, fatigue, headache, dizziness, nausea and other ailments.

The BioFilter purifies the air through a system that combines activated carbon and other filter media with living plants and microorganisms. The adsorptive filter material traps and holds the indoor pollutants. The plant roots and microorganisms living on and around the roots convert the pollutants into food for the plant.





Most non-flowering house plants will work; Terra Firma supplies a list of those that have tested best. The plant is grown hydroponically (without soil) in the filter media. Contaminated air is pulled into the system by a small fan. After smoke, odors, chemicals and other pollutants are removed by the filter media and plant roots, the cleansed air is returned to the room through slits in the planter.

Terra Firma is developing a self-cleaning filter that removes pollutants from the air and disinfects the air as well. An upgraded version of the Biofilter 2000, it will use plants, microorganisms and activated carbon filtration to clean the air and an ultraviolet source to rid the air of harmful mold, bacteria and viruses. Dr. Wolverton is again serving as a consultant to Terra Firma on the new product, to be introduced in 1993. ●

ORIGINAL PAGE
COLOR PHOTOGRAPH

Light Source

RESEARCH ON FOOD

GROWTH FOR LONG

DURATION SPACECRAFT

YIELDS A LIGHT

SOURCE FOR GROWING

PLANTS INDOORS

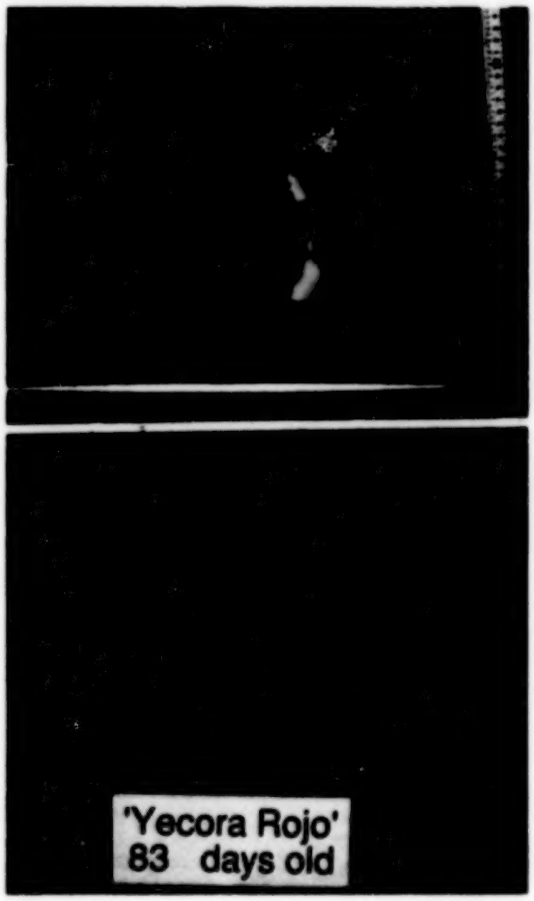
In the ***top photo*** is a QBeam™ solid state light source consisting of a control unit and a lamp. The hand covering the lamp evidences that the box-like red light source is putting out very little heat although it is generating high intensity radiation. Used as a light source for plant growth and photosynthesis research, the QBeam is marketed by Quantum Devices, Inc. (QDI), Barneveld, Wisconsin, a company formed to pursue the commercial application of light emitting diodes (LEDs) as a plant lighting source.

QDI, headed by president Ronald W. Ignatius, evolved out of cooperative efforts with the Wisconsin Center for Space Automation and Robotics (WCSAR) at the University of Wisconsin in Madison. WCSAR is one of NASA's Centers for the Commercial Development of Space; Ignatius represented a company that was one of WCSAR's industrial partners.

WCSAR was conducting research on light sources for promoting food growth in a closed environment, such as a space station or a long duration manned spacecraft. The kind of lighting used in plant research facilities on Earth has many drawbacks for space use, notably short lifespan, poor energy efficiency and too much heat output. WCSAR and Ignatius began experimenting with LEDs, which offer high energy efficiency and give off virtually no heat; research had shown that red LED wavelengths are very effective in promoting plant growth and photosynthesis (***at right*** is a WCSAR experiment in controlled growth of wheat using a double array of LEDs). QDI was successful in developing a line of LED products specifically designed as red radiation sources for plant growth.

Ignatius founded QDI in 1990 to market the LED technology, which has commercial applicability for growing plants indooors and for commercial plant growing operations such as greenhouses, and to produce a line of wavelength-specific LEDs tailored to a customer's requirements. QDI, in conjunction with another Wisconsin company, has advanced the technology and expanded the range of applications to include medical devices; an initial LED-based cancer treatment device is targeted for human clinical trials in 1993. ●

™ QBeam is a trademark of Quantum Devices, Inc.



ORIGINAL PAGE
COLOR PHOTOGRAPH

Meteorological Software

A NASA COMPUTER PROGRAM ADVANCES INSTRUCTIONAL TECHNIQUES IN METEOROLOGY TRAINING

Millersville University, Millersville, Pennsylvania conducts a comprehensive meteorology program as a component of its Department of Earth Sciences. The department prides itself on its employment of state-of-the-art tools for its meteorological instructional classes and research projects. Among those tools is a NASA-developed computer program known as GEMPAK (General Meteorological Package).

In the classroom, a data line feed is ingested and stored in GEMPAK files with the data processed and displayed by means of text-based menu selection schemes. This allows classes —such as Synoptic Meteorology — to analyze and interpret multiple products and make students aware of the often difficult and varied analysis techniques that previously were only treated as theoretical concepts.

An example is shown in the computer screen display (***bottom***) of a meteorological parameter known as "isentropic potential vorticity;" GEMPAK makes possible such displays by embedding device drivers within the software. ***Below right***, Millersville student Pat Market is using standard meteorological data from 12 different days in a search for sub-synoptic scale (less than 200 kilometers) factors that might lead to tornado formation in the mid-Atlantic region. GEMPAK's streamline and contouring routines allow for standardization of the methods as well as calculations of more complex derived products.

GEMPAK was supplied to Millersville University by the Computer Software Management and Information Center (COSMIC)*, NASA's mechanism for making available to industry, academic and government clients computer software originally developed by government agencies that has secondary utility (see page 140). ●

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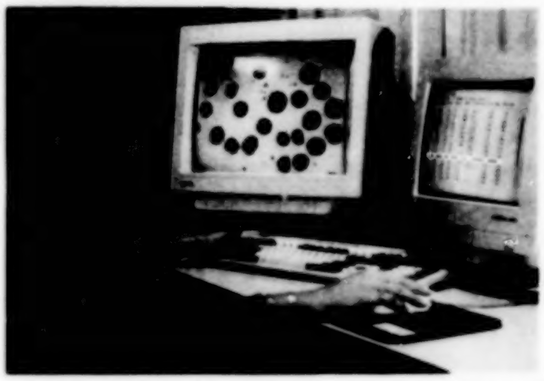
* COSMIC is a registered trademark of the National Aeronautics and Space Administration.

Image Processing

TECHNOLOGY FOR SPACE SHUTTLE IMAGE PROCESSING GENERATES COMMERCIAL SOFTWARE WITH BROAD APPLICABILITY

B*elow*, a computer operator is conducting an electronic count of the trees in an orange grove, using the innovative ImageCount software, an advanced program for defining, counting, numbering and measuring objects in imaging files and captured video frames.

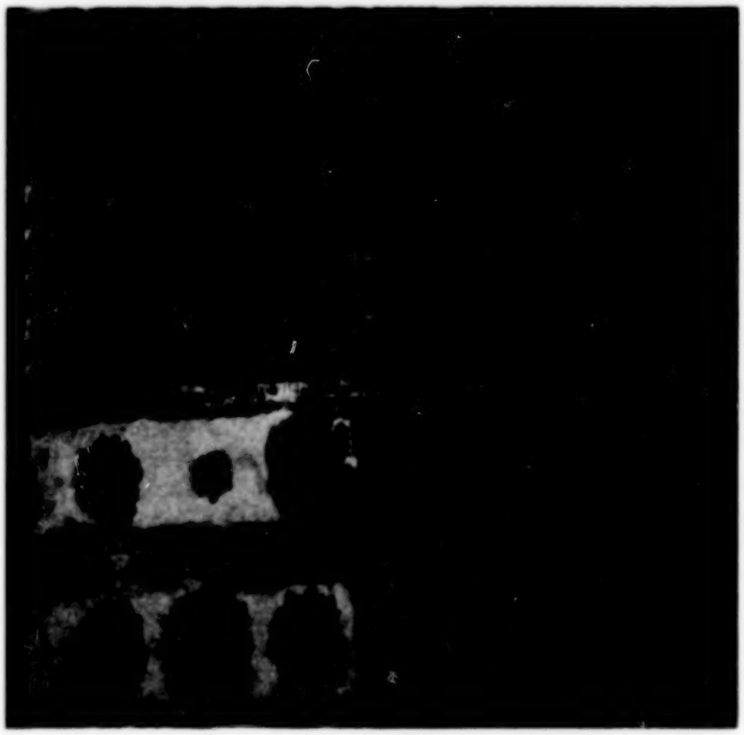


At right, digitized scaling of an aerial infrared image shows a Florida orange grove in various degrees of detail.

Developed by Electronic Imagery, Inc. (EI), Delray Beach, Florida, ImageCount stems from the same core technology as ImageScale Plus, a related software package developed for NASA by EI under a Small Business Innovation Research (SBIR) contract. ImageScale Plus made it possible for astronauts to conduct image processing and prepare electronic still camera images in orbit aboard the Space Shuttle Orbiter, display them on small monitors in the Orbiter, and downlink images to scientists on the ground for evaluation while the flight is in progress. Introduced to Shuttle service in September 1991, ImageScale Plus has been in regular use on Shuttle flights since.

EI's work under the SBIR contract spawned commercial spinoffs in several directions. ImageScale Plus is used in scientific applications such as x-ray and magnetic resonance imaging, and in ophthalmological applications. General commercial applications include prepress, document processing, textile design and special effects for motion pictures. The technology developed under the SBIR also facilitated database management and networking of high definition digital images in the medical, scientific and industrial fields using EI's Image Manager software and it enabled EI to adapt the core technology to processing aerial photography imagery and to package it into the software system that became ImageCount.

The tree counting application has broad potential; it offers great time savings compared with alternative methods of inventorying citrus groves for tax purposes: either actual counting of individual trees by field crews, or laborious hand counting of trees in aerial photos. ImageCount also permits computer analysis of the trees for apparent health, an aid in crop forecasting. ●



Radiation Insulation

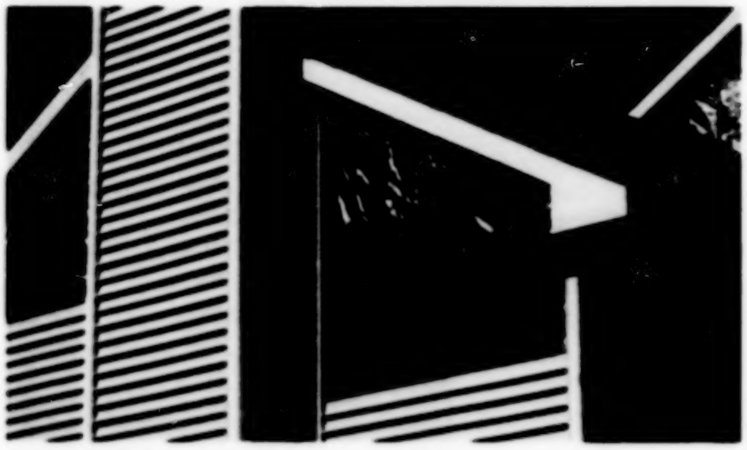
The Apollo spacecraft represented a masterpiece of temperature control technology. It had to be, to protect astronauts from temperatures that ranged 400 degrees above and below zero Fahrenheit.

A prime element of the environmental control system that permitted astronauts to work inside the Command Module in shirtsleeves was a highly effective radiation barrier. Made of aluminized polymer film, it barred or let in heat to maintain a consistent temperature in an environment where ordinary insulative methods would not have sufficed. The key was aluminization of the material, which provided a reflective surface that kept more than 95 percent of the radiated energy from reaching the spacecraft's interior.

MOONCRAFT TECHNOLOGY GIVES RISE TO A HIGHLY EFFECTIVE EARTH-USE INSULATION

The radiation barrier technology has since been used on virtually all spacecraft, including unmanned spacecraft where delicate instruments need protection from extremes of temperature. It is also a key element of a sophisticated energy conservation technique for home and office building installations, plus a variety of special applications, for instance as a candy wrapping to protect the product from heat or cold during transit.

An example of companies supplying variations of the space-derived material is Buckeye Radiant Barrier, Dayton, Ohio, which markets a lightweight aluminized material known as "Super R" Radiant Barrier, manufactured by Radiant Technologies, Inc., Richmond, Virginia.

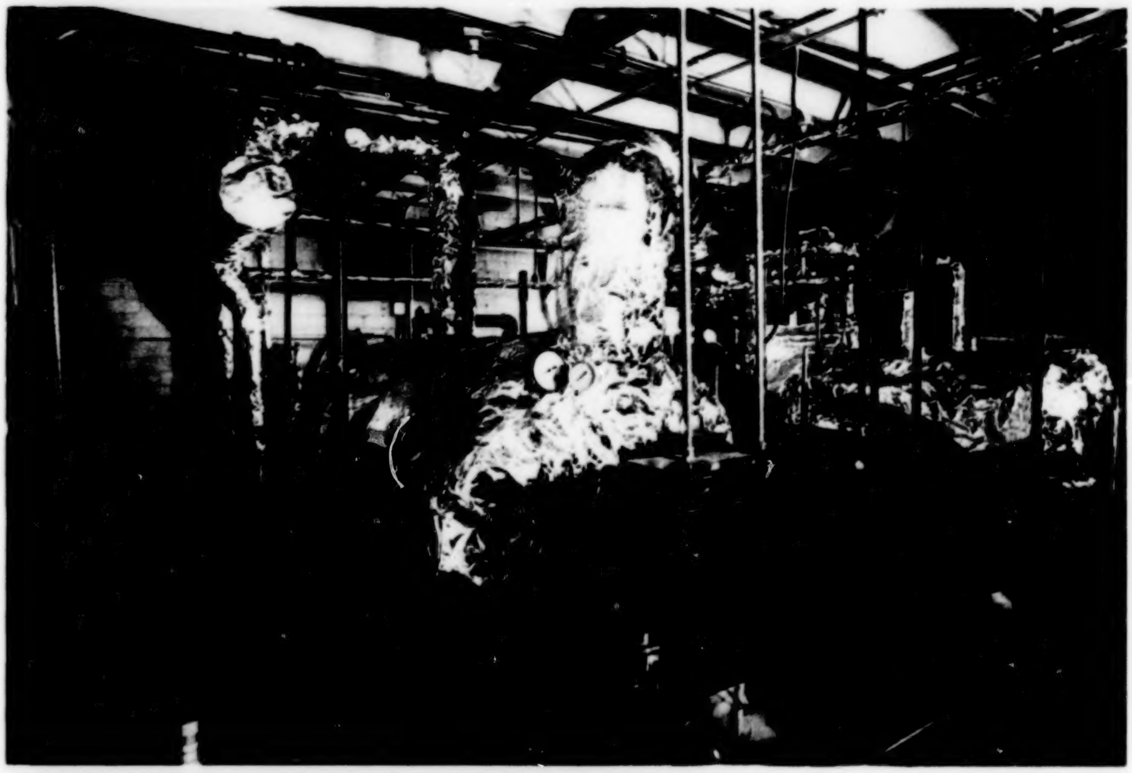


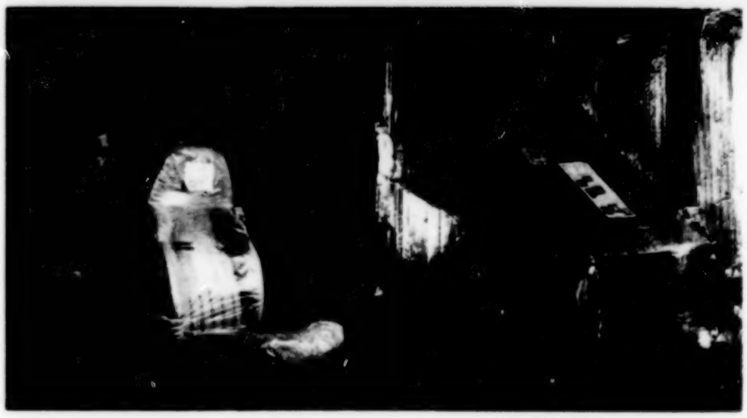
The accompanying photos illustrate some applications of the material supplied by Buckeye. ***At top*** is a new home construction application; the radiant barrier is placed between the wall studs and the exterior facing prior to the addition of aluminum, vinyl or wood siding. In a new roof installation (***middle photo***) the barrier is placed between the roof supports and the roof sheathing. For retrofitting existing homes, the perforated Radiant Barrier tops insulation blankets on an attic floor to reflect energy (***above***). The ***upper right photo*** shows the product applied to a commercial gas-fired boiler room in a school; prior to the installation, the room above the boiler room was uninhabitable as a classroom, but the Radiant Barrier corrected the problem. The ***bottom photo*** illustrates an industrial application in which the Radiant Barrier is used to increase the performance of a shrink wrap oven by reflecting the energy inward; the oven is used to shrink plastic protective coverings over auto seats prior to shipping.

For these and other terrestrial applications, suppliers claim the Radiant Barrier offers a decrease in utility bills of 20 percent or more. The material focuses on controlling radiant heat (as opposed to conductive heat, the direct flow of heat through solid objects, or convective heat, the upward flow of air due to its expansion as it warms). Radiant heat is the flow of invisible infrared rays from the surface of an object; all objects radiate, for example, the emittances from wood, glass, insulation and even ice.

The Radiant Barrier blocks these emittances by reflecting back 95 percent of all radiant energy, thus keeping heat in the building in the winter and blocking it out in the summer, with beneficial impact on energy bills.

"Super R" Radiant Barrier supplied by Buckeye is a three-layer material that includes two layers of 99 percent pure aluminum foil separated by a layer of polyprophylene (to act as a thermal break) and by a nylon grid that provides strength. The sheets are perforated to allow moisture to escape. ●





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COLOR PHOTOGRAPH

HIGH TECH ART: CHAMELEON GLASS

A UNIQUE ART FORM DERIVED FROM AEROSPACE OPTICAL RESEARCH LEADS A SELECTION OF TECHNOLOGY TRANSFERS FOR CONSUMER, HOME AND RECREATIONAL USE

Dichroic" is a word you won't hear very often in everyday conversation. It means, in its simplest form, "two-colored." In optical industry parlance it refers to a light beam that is one color when transmitted and a different color when reflected.

Dichroic glass, developed in the 1950s and 1960s by NASA, the Department of Defense and their contractors, is a technology wherein extremely thin films of metal are vacuum deposited on a glass surface. The coated glass shields sensitive spacecraft instruments from the harmful effects of cosmic radiation or protects human vision from the harsh glare of unfiltered sunlight in space.

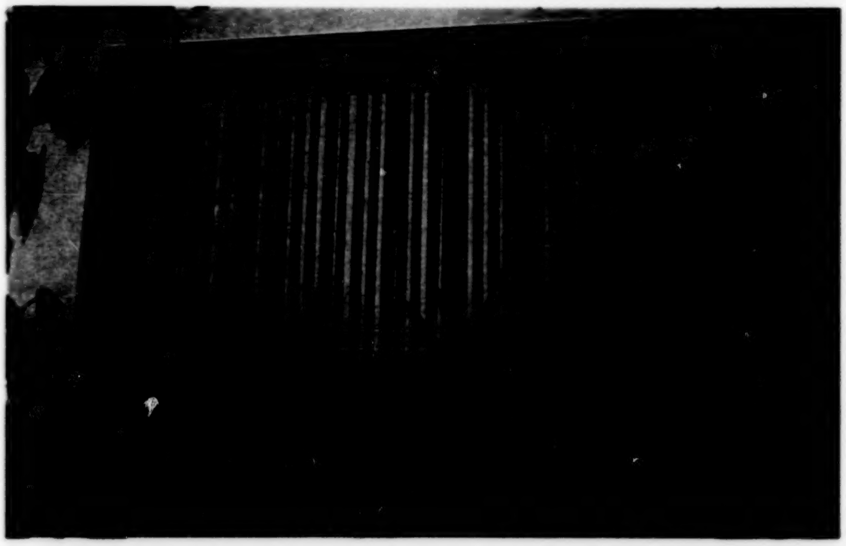
In their Venice (California) studio, Murray Schwartz (left), and assistants Diane Gerard (center) and Nina Chesnonis display some of their internationally-known Kroma line of dichroic glass artworks. At top right is an etched dichroic panel and at lower right a sampling of Kroma dichroic glass jewelry.

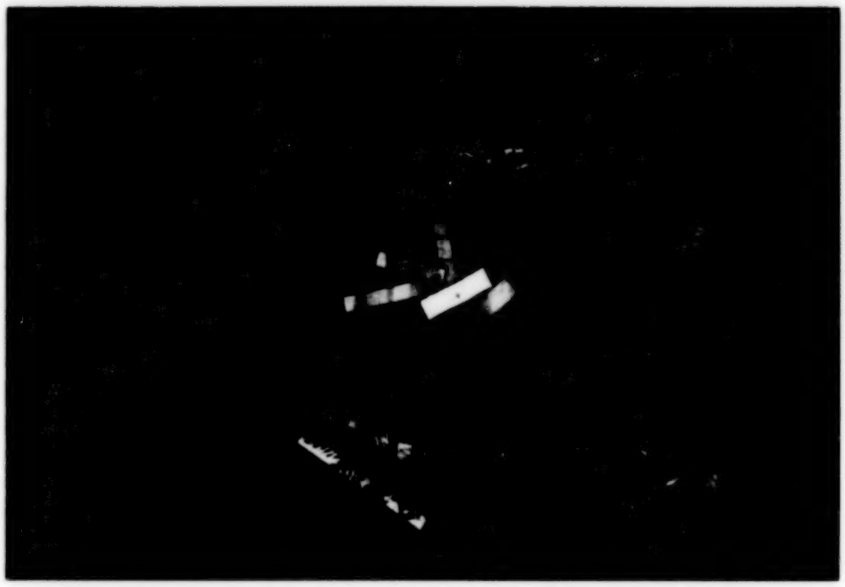
The development of dichroic glass serendipitously created a new high tech art form, because the process of coating glass with thin film metal allows some wavelengths of light and color to reflect, while other wavelengths pass through. This produces a chameleon effect in which the color of the glass changes with the amount of light being absorbed or reflected, generating shifting patterns of exceptional beauty.

One aerospace engineer who was particularly impressed by the beauty of the chameleon glass was Murray Schwartz who, in the 1960s, worked for Wallin Optical Systems, Tarzana, California, a NASA contractor providing design services on such projects as optical relay systems and beam expanders.

"I was very much interested in thin film physics," Schwartz recalls, "and I also had a keen attraction to dichroic glass which, in the purity of its narrow bands of color, is overwhelmingly beautiful. When coupled with the feature of colors that change, the material is quite fascinating, almost magical, and certainly appealing. So I decided to make a little business out of it."

In 1971, Murray Schwartz left the aerospace industry and turned his attention to creating dichroic stained glass windows, mobiles and other artworks. Schwartz is an unusually talented optics engineer and this form of art demands that the creator be more scientist/technologist than artist. The technique involves deposition of superthin layers of metal oxides — measured in millionths of an inch — using many different types of metals,





sometimes as many as 50. The metal films are applied one layer at a time, in a specific order and in specific thicknesses, to get the effect the artist seeks.

For several years, Murray and his daughter Regina Standel traveled the West Coast in a van, selling artworks at craft fairs. In 1976, they set up a studio, now known as Kroma, Inc., in Venice, California.

It was in Venice — in 1985 — that Murray met and married Rupama Schwartz, who is also a glass expert and an authority on glass fusing. Rupama was instrumental in introducing glass necklaces, pins and earrings to the Kroma product line. In 1993, Kroma moved to Santa Fe, New Mexico.

In relatively few years, Murray Schwartz's "little business" has become a highly successful enterprise manufacturing stained glass windows — which go for as much as $20,000 — mobiles, masks, jewelry, lamps and other ornamental products, all made exclusively with dichroic glass. The excellence and uniqueness of the product line has spawned a following of art collectors, including a number of Hollywood personalities. The trade name Kroma is known internationally and the Schwartzes now rank among the foremost practitioners of the new high tech art form. ●

Heat Pipe Systems

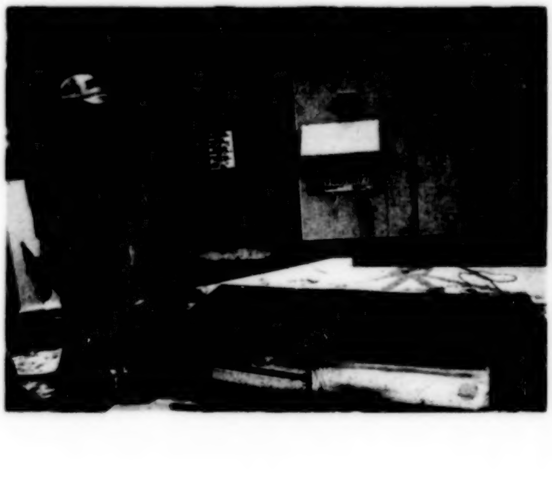
SPACE-DERIVED HEAT PUMPS OFFER RESTAURANT CHAINS AN ANSWER TO HUMIDITY PROBLEMS

In the early days of the space program, NASA encountered a problem: the Sun-facing surfaces of a non-rotating spacecraft became excessively hot while surfaces not exposed to the Sun became very cold. Since that situation could cause failure of electronic systems, NASA teamed with Los Alamos Scientific Laboratory to find a solution. The highly effective answer they found was a simple heat transfer mechanism called the heat pipe.

The heat pipe is a sealed tube containing a small amount of liquid refrigerant. In a multiple heat pipe system, each pipe is inclined so that the refrigerant flows by gravity to the lower end. The low end is an evaporator, the high end a condenser. When the refrigerant flows to the low end, it evaporates and absorbs heat in the process. The low density vapor then rises to the high end, where it releases heat and condenses into a liquid to repeat the cycle. This technology provides a system that alternately cools and heats without use of energy or any moving parts.

Successful space use of heat pipes over two decades underlined the Earth-use potential of the technology and, in the 1980s, NASA initiated an effort to promote its broader use. The Southern Technology Applications Center, Gainesville, Florida and the Florida Solar Energy Center teamed with a commercial firm to develop a prototype heat pipe system for terrestrial use. Subsequently a number of other organizations joined NASA in a broad program to refine the technology, demonstrate it and commercialize it; among the participants are Edison Electric Institute, Florida Power Corporation, Georgia Power Company, Alabama Power Company, Mississippi Power Company, Wisconsin Electric Power Company and Carrier Corporation. Several supermarket chains participated in heat pipe air conditioning/dehumidification demonstrations in six states.

More recent demonstrations have involved fast food chains such as Burger King Corporation, Miami, Florida and Taco Bell Corporation, Irvine, California. Fast food restaurants have special problems in areas of high humidity because of cooking processes, customer load and code requirements concerning the rate of movement of outside air to the building's interior. Extremely humid interior conditions cause restaurant fixtures and building materials to deteriorate at an accelerated rate due to interior water condensation; they also result in increased costs of



energy and repair or replacement of equipment.

Under the sponsorship of Edison Electric Institute, Florida Power conducted a heat pipe dehumidification research project for Burger King with the assistance of Tropic-Kool Engineering Corporation, Largo, Florida. Heat Pipe Technology, Alachua, Florida supplied and installed the heat pipes.

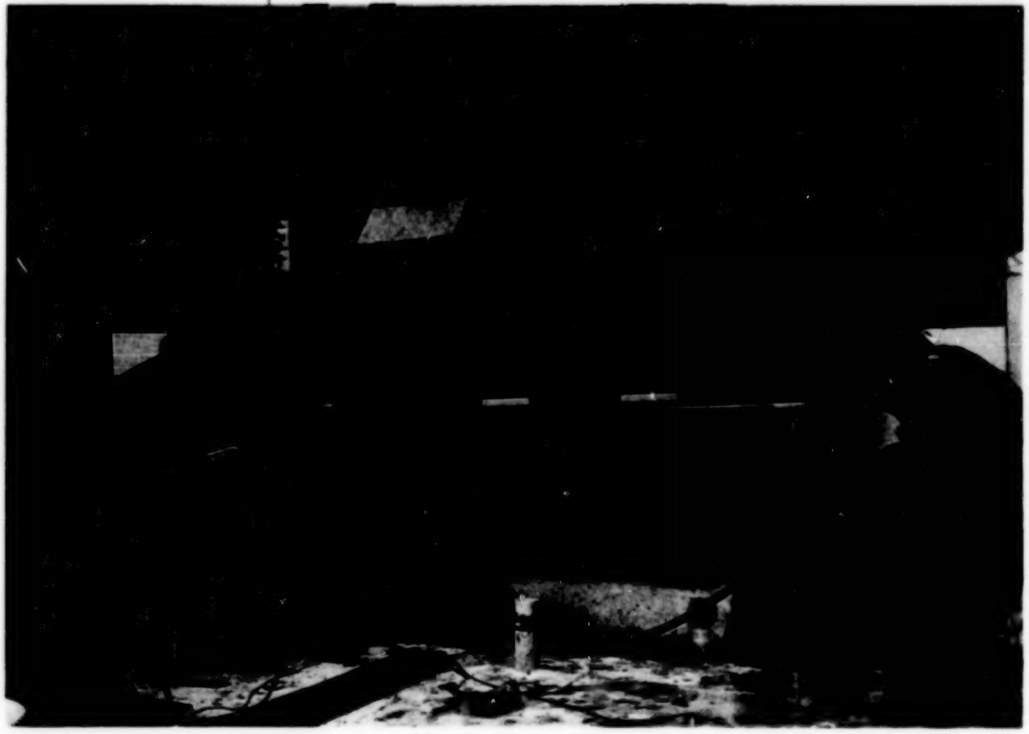
A Burger King restaurant in Clearwater was selected as the pilot project site. Florida Power engineers set up test equipment to track temperature, humidity, condensate flow and power consumption.

After six months an analysis of the data showed a 30 percent improvement in the moisture removed by the air conditioners, a 10 percent decrease in relative humidity, and a 17 percent reduction in HVAC power consumption, all due to the work of the heat pipes.

In another project at an Atlanta (Georgia) Burger King, Georgia Power recorded similar results with power consumption reduced by a very impressive 28.6 percent. In the ***far left photo***, a Tropic-Kool technician is removing the existing HVAC system at the Atlanta Burger King; in the ***adjacent photo***, the heat pipe system is being installed; ***below left***, the HVAC system is being reinstalled atop the heat pipe unit.

Says Alan Robart, director of construction for Burger King's Real Estate Division, "After many successful, utility-funded tests in several parts of the country, Burger King is developing a program that may make heat pipes standard in its restaurants."

Taco Bell Corporation similarly found heat pipes the answer to problems with high humidity. Tropic-Kool Engineering proposed a demonstration of what heat pipes could do to increase the latent capacity of air conditioners.



A Taco Bell restaurant in St. Petersburg, Florida was selected as the test site. Tropic-Kool secured the cooperation of Edison Electric Institute and Florida Power for monitoring the project. Heat Pipe Technology designed and installed a heat pipe system (***above***). An analysis showed a 25 to 30 percent reduction in humidity levels and a 38 percent increase in condensate flow levels. After a further series of tests in a number of U.S. locations, Taco Bell now specifies that all new restaurants in the southeastern United States will be equipped with heat pipe systems. ●

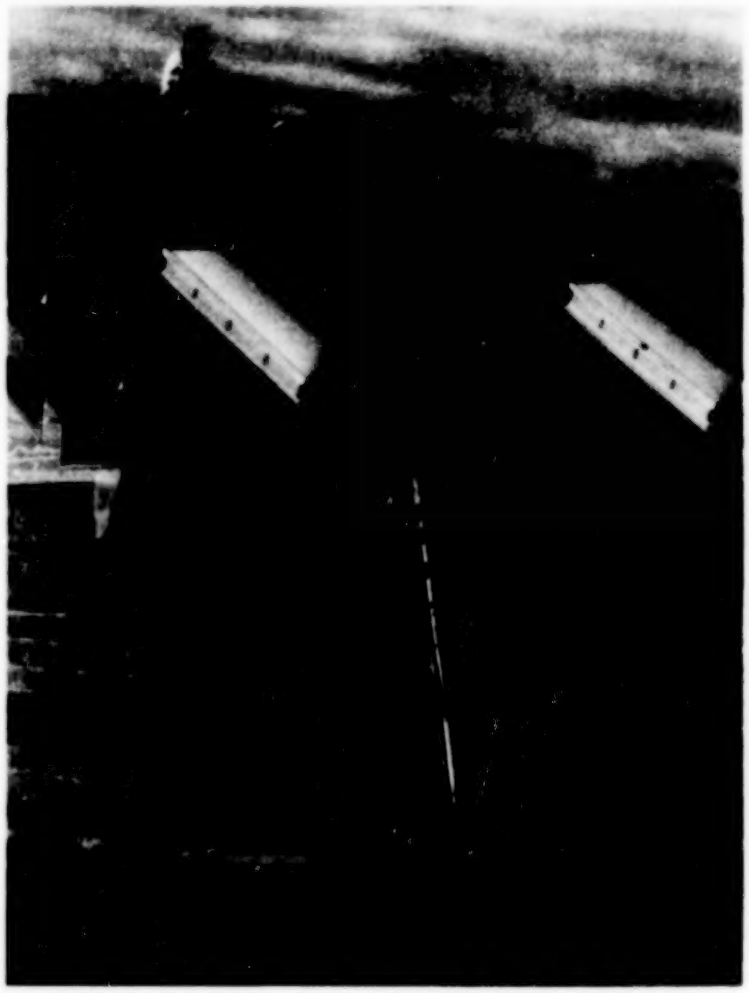
ORIGINAL PAGE
COLOR PHOTOGRAPH

Solar Water Heater

AN ENGINEER'S NASA-ACQUIRED KNOW-HOW SPAWNS A NEW TYPE OF SOLAR WATER HEATER

A*t right*, Dr. Eldon Haines of Sage Advance Corporation, Eugene, Oregon is installing a collector of the novel Copper Cricket™ solar water heating system he designed. ***Shown below*** is a U.S. Forest Service (USFS) installation at Tonto (Arizona) National Forest of Sage Advance's Copper Dragon™, a larger system that in this installation provides hot water for restrooms and shower facilities in a USFS campground site. Both systems represent technology transfers of the personal know-how variety, because they are based on expertise acquired by Dr. Haines during his 13 years service with Jet Propulsion Laboratory, a NASA field center.

Dr. Haines' patents in "geyser pumping" and bubble nucleation, the basis of Sage Advance's systems, are an outgrowth of his NASA experiences. While at JPL, Dr. Haines' work led him to study the solar energy source and the state of the art of solar water heating. He concluded that he could build a superior solar hot water heating system by employing the geyser pumping principle in a device that combines the best features of active and passive systems.



In 1977, Eldon Haines resigned from JPL to devote full time to development of his system. A decade later, with two associates, he formed Sage Advance to market the geyser pumping technology. The company's initial project is the Copper Cricket residential unit, designed to provide 50-90 percent of the hot water requirements for an average person household; it has no moving parts, is immune to freeze damage, needs no roof-mounted tanks and features low maintenance. Sage Advance later expanded the product line to include the Copper Dragon large commercial arrays.

Dr. Haines remains with the company as vice president for research and development, and he continues working for NASA as a consultant. ●

™ Copper Cricket and Copper Dragon are trademarks of Sage Advance Corporation.

Water Filters

A NEW FAMILY OF FILTRATION DEVICES STEMMED FROM APOLLO SPACECRAFT TECHNOLOGY

At left below, is an Aquaspace* H$_2$OME* Guardian Water Filter, which features a capability for reducing lead in water supplies to alleviate a problem that is gaining national attention; the filter is mounted on the faucet and the filter cartridge is separately mounted in the "dead space" between sink and wall. Manufactured by Western Water International (WWI), Forestville, Maryland, the H$_2$OME Guardian filter was recently certified by National Testing Laboratories for more than 1,000 gallons of lead reduction.

The H$_2$OME Guardian filter is one of several new members of a family of filtration devices that use the Aquaspace Compound Filter Media, which combines WWI technology with NASA technology originally developed to sterilize the drinking water of the Apollo spacecraft. Aquaspace Compound is a proprietary WWI formula that blends various types of activated charcoal with other active and inert ingredients to remove toxic contaminants, organic chemical compounds, chlorine and other water processing agents, unpleasant taste, color and odor.

WWI founder and president Paul M. "Mike" Pedersen, while conducting his own investigation toward a more effective method of filtering potable water, learned that NASA had conducted extensive research in water purification for manned spacecraft. He obtained a number of NASA technical reports and applied the information to his own research. NASA information that contributed importantly to the development of Aquaspace Compound, Pedersen states, included technology related to the use of ions as filtering agents and methods dealing with the absorption and adsorption of organic compounds.

Ranging from simple pocket filters to high capacity units serving whole communities in developing nations where water is highly contaminated, Aquaspace filters are finding wide acceptance in industrial, commercial, residential and recreational applications. ***Shown below*** is a large under-the-sink Aquaspace unit. ●

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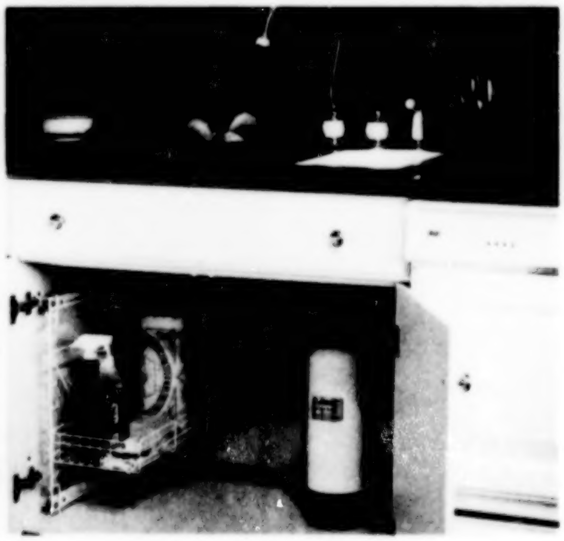
* Aquaspace and H$_2$OME are registered trademarks of Western Water International, Inc.



ORIGINAL PAGE
COLOR PHOTOGRAPH

Motion Simulator

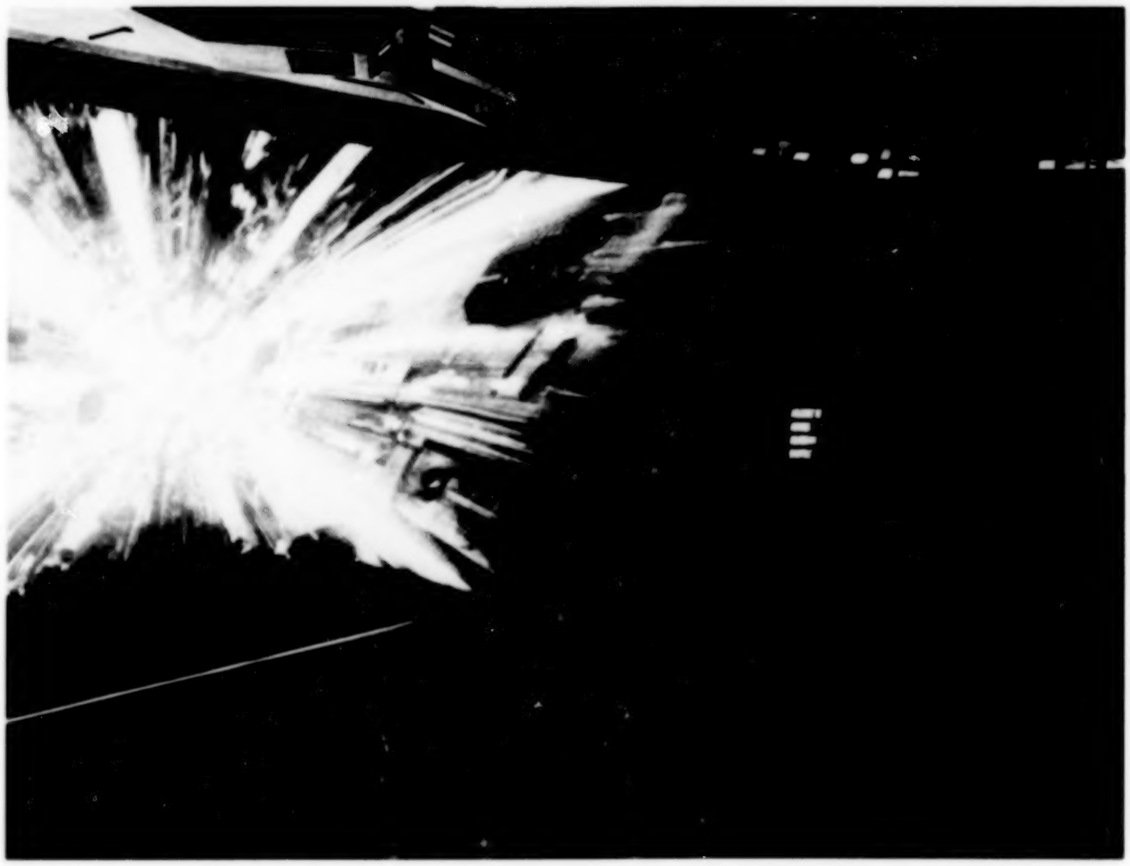
SPACE SHUTTLE TECHNOLOGY IS INCORPORATED IN A NEW RECREATIONAL ATTRACTION

Shown below is a model of the Magic Motion Simulator™ 30 Series, a cabin flight simulator for science museums and recreational attractions produced by InterActive Simulation Inc. (ISI), Toronto, Ontario. ISI pioneered the use of flight simulators as theater attractions and is the world's leading supplier of simulator-based attractions; the 30 Series machines are the first electric-powered simulators and the electric motion actuators they employ are products of space technology.

The full size simulator made its debut as a 30-seat theater at the U.S. Space and Rocket Center, Huntsville, Alabama, ISI's first customer for electric simulators. Opened to the public on May 15, 1993, the Space and Rocket Center's unit takes passengers on a realistic flight to Jupiter.

The electric motion system, developed by MOOG, Inc.'s Motion Systems Division, East Aurora, New York, generates a quiet, smooth, powerful range of computer-guided motions — including simulated free fall — to heighten the sense of moving through space. Motion is coordinated with visual effects provided by a MotionVision 70™ projection system; the system projects a 70 millimeter image onto a 15 by 7-foot curved screen that fills the viewers' peripheral vision. Realism is further heightened by a digital laser-based sound system with 11 speakers.

Below is a view from the interior of the cabin of the Space and Rocket Center's simulator; the image on the screen is a space view but it can be any kind of environment that can be filmed, for example, a trip to the ocean depths.



At right is a closeup view of the electric actuators that move and shake the cabin.

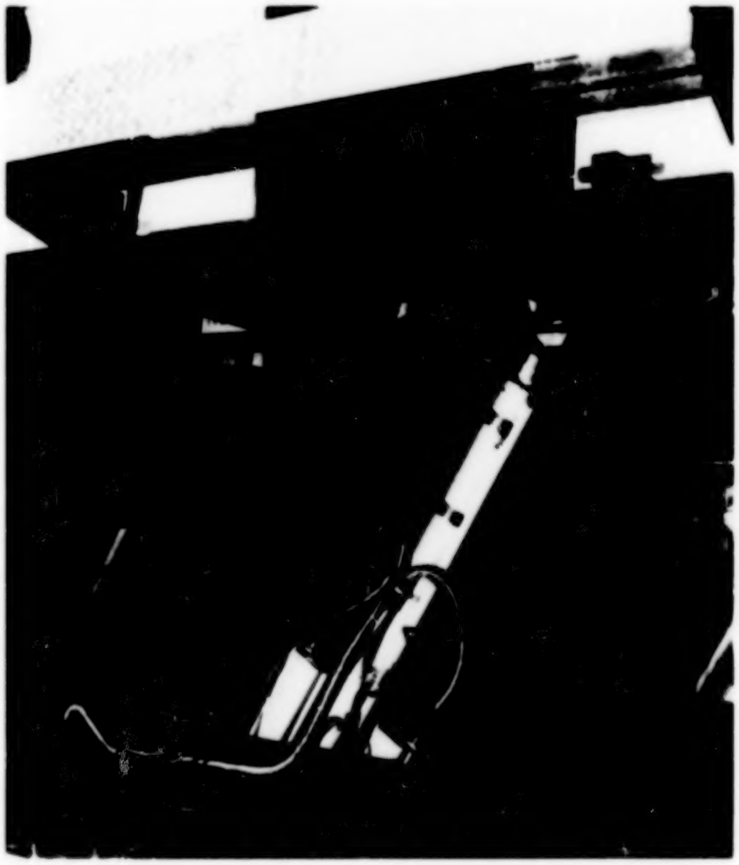
The development of the electric actuator represents an unusual case of space technology transfer wherein the product was commercialized before it was used for the intended space purpose. MOOG, which supplies the TVC (thrust vector control) hydraulic actuators for the Space Shuttle and brake actuators for the Shuttle Orbiter, initiated development of electric actuators for aerospace and industrial use in the early 1980s. By 1989, the company had successfully developed units with peak power ratings as high as 10 horsepower. At that time, MOOG learned that NASA was interested in electric actuators for a possible next generation Space Shuttle or for a new, advanced launch system being studied.

After discussions with Shuttle contractors and officials of Marshall Space Flight Center (MSFC), MOOG decided — in 1990 — to go ahead, under company funding, with design and demonstration of an electric replacement for the Shuttle main engine TVC actuator. This represented a significant development, because the TVC actuator would require a peak power of 40-plus horsepower and other technological advancements to compete with hydraulic actuator performance and durability.

MSFC cooperated in the development by providing MOOG design information relative to TVC operating data and system performance. MSFC also participated in a number of technical interchange meetings with MOOG engineers to assess program status and to exchange information on design progress and test requirements. MOOG delivered a completed unit to MSFC for an evaluation, which is still in progress.

Having advanced the art of electromechanical motion control, MOOG decided to pursue the commercial potential by initiating development of an electrically actuated motion system capable of manipulating a load of 13,000 pounds in four degrees of freedom. That led to the partnership with ISI for production of cabin flight simulators.

The advantages of electric actuation — in comparison with the hydraulic actuators used in prior ISI simulators — include easy installation and reduced environmental risk, along with lower operating costs, noise, heat, maintenance and staff requirements. In addition to the Space and Rocket Center's unit, ISI has delivered simulators for the Canadian Pavillion of the Taejon (Korea) Expo '93 and a museum at the City of Science and Technology, La Vilette Parc, Paris. ●



™ Magic Motion Machine and MotionVision 70 are trademarks of InterActive Simulation, Inc.

Radiation Blocking Lenses

NASA INDUSTRIAL SAFETY TECHNOLOGY YIELDS SUNGLASSES THAT BLOCK EYE-HARMFUL RADIATIONS

Below, former America's Cup yacht-racing champion Peter Isler is modeling a new type of sunglasses, the polarized Eagle 475 produced by Biomedical Optics Company of America, Inc. (BOCA), North Hollywood, California.

The Eagle 475 lens represents a spinoff from a spinoff. It is a BOCA advancement of a NASA-derived technology used in the 1980s as the basis for the Suntiger line of sunlight-filtering lenses that protect human vision by blocking potentially harmful blue, violet and ultraviolet light. In 1991, BOCA acquired the rights to the Suntiger technological processes and conducted further development of the lens.

The Eagle 475 is designed to absorb 100 percent of all photowavelengths considered hazardous to eye tissue, including ultraviolet and blue light. The "475" designates the point at which visible light is allowed to transmit through the lens, in technical language 475 nanometers. According to BOCA, there is scientific evidence that this is the point most beneficial to the human eye, not only in protection from the Sun but in increased visual perception, contrast and reduced chromatic aberration (blue light haze).

Ultraviolet and blue light have been identified as contributors to cataract and age-related macular degeneration (retinal damage). Selective light filtration, a feature of the Eagle 475 lens, absorbs the hazardous wavelengths while allowing a higher percentage of visually useful areas of the spectrum to pass through. Polarization blocks out irritating glint and glare and heightens visual acuity.

The Eagle 475 product marks the latest evolution of a series of spinoffs that originated more than a decade ago in research performed by James B. Stephens and the late Dr. Charles G. Miller, both of Jet Propulsion Laboratory. Drawing on NASA radiation know-how and problem-solving methodology, the JPL duo conducted an industrial research project intended to develop a protective welding curtain that filtered out harmful irradiance, in particular blue light. Their successful effort resulted in a formula that included light filtering dyes and small particles of zinc oxide, and produced a commercial curtain that absorbs, filters and scatters light and thus provides protection for industrial personnel in welding areas. That success led to further research focused on protective industrial glasses and eventually to the Suntiger line of consumer products. ●

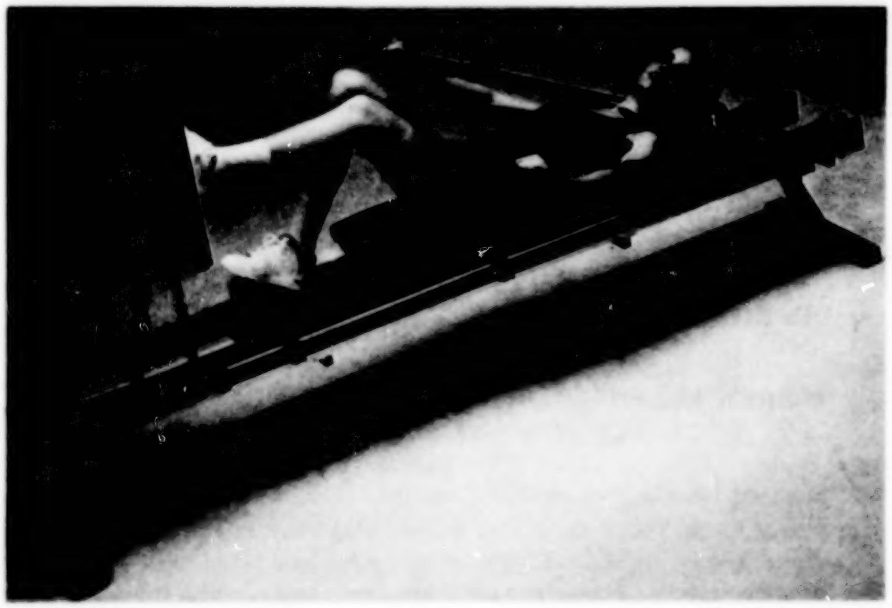
ORIGINAL PAGE
COLOR PHOTOGRAPH

Cardio-muscular Conditioner

SPACE STATION STUDIES GENERATED TECHNOLOGY FOR AN ADVANCED CONDITIONING MACHINE

Shown below is the Shuttle 2000-1 physical therapy and athletic development conditioner, an exercising device that traces its technological lineage to studies performed in the 1960s on "cardiovascular deconditioning," the potential loss of integrity of an astronaut's cardiovascular system due to prolonged exposure to the microgravity environment of space.

The Shuttle 2000-1 was designed and developed by Gary Graham, founder and president of Contemporary Design Company, Glacier, Washington, which manufactures and markets the device.



Used by the National Football League's New York Giants and Jets, university strength coaches, operators of sports clinics and medical rehabilitation centers, the exerciser is, in effect, a "horizontal trampoline." Originally conceived as an exerciser for use aboard a space station to avoid cardiovascular deconditioning, the Shuttle 2000-1 promotes cardiovascular fitness and muscular strength development through both closed-chain kinetic and plyometric exercises (plyometrics are designed to stress the body in such a way that it produces faster and stronger muscle contraction).

The athlete (or rehab patient) lies on a cushioned carriage that glides between two rails, propelled by the user as he pushes off a kick plate. Resistance is provided by elasticords running the length of the machine; the user can add or remove elasticords to increase or decrease resistance. The elasticords provide a rebound effect by returning the user to a neutral position after a push-off. The rebound feature, says designer Graham, is the principal difference between the Shuttle 2000-1 and other exercisers, because it combines internal and external induced stresses.

External stress comes from the full range of motion of the arms and legs during exercise; all four limbs may propel the Shuttle independently or simultaneously. Internal stress occurs when the user pushes off the kick plate. The accelerated load caused by the rebound system induces a movement of the diaphragm, which can cause a change in chest cavity volume. When the diaphragm moves downward, a negative pressure develops in the chest cavity, thus attracting blood toward the heart.

Gary Graham's initial work in this area came in the mid-sixties when, as an employee of The Boeing Company, he was a member of a design team responsible for developing a cardiovascular conditioner for a then-planned — but never built — Air Force orbiting laboratory. After the Air Force project was cancelled, Graham participated in space station conditioning studies during NASA's Apollo Applications (later Skylab) program. The expertise thus acquired lay dormant until 1985 when Graham decided to revive the conditioner as an Earth-use system. He enlisted the aid of Gary Chase, an exercise physiologist who had also been a member of the Boeing design team. In 1987 Graham patented a first generation system known as the CMC Shuttle 2000, which was refined and introduced to the market as the Shuttle 2000-1 in 1991. ●

ORIGINAL PAGE
COLOR PHOTOGRAPH

ROBOTS FOR AIRCRAFT MAINTENANCE

On a Space Shuttle launch, the two solid rocket boosters fire for two minutes as the Shuttle drills its way through the atmosphere to an altitude of about 25 miles. Then they separate from the orbit-bound Shuttle "stack" and drop Earthward to a parachute-softened splash in the ocean. They are retrieved by recovery teams and delivered to a land facility for refurbishment and reuse.

Above is an ARMS robotic workcell operated by Delta Air Lines to remove coatings from jet engine components during overhauls. At right is a closeup of the business end of the robot arm — the end effector — removing the liner (the waffle-like substance).

An early step in the refurbishment process is stripping the paint and thermal protection material from the booster segments. Removal of the thermal protection material is a particularly difficult job. Designed to protect the rocket from the intense heat of atmospheric friction, the material is extremely tough and removal-resistant. It must not only be removed, it must be taken off in such a manner that the casing of the booster segment is not damaged.

HEADING SPINOFFS IN THE FIELD OF TRANSPORTATION ARE NEW ROBOTIC WATERJET CLEANING SYSTEMS DERIVED FROM SPACE SHUTTLE TECHNOLOGY

In the early days of Space Shuttle development, NASA realized that something substantially better than conventional manual stripping techniques would be required for booster refurbishment. Accordingly, Marshall Space Flight Center and a contractor initiated development of an advanced stripping system based on hydroblasting, or high pressure waterjet cleaning. The contractor selected was United Technologies' USBI Company, Huntsville, Alabama, NASA's contractor for Shuttle recovery and refurbishment operations at Kennedy Space Center (KSC).

The original system consisted of a fixed, gantry-mounted robot and a turntable in an enclosed workcell. A later development, now in use at KSC, is the Mobile Robotic Hydroblast System, which can be driven directly to the site of booster processing to provide initial waterjet stripping prior to disassembly of the booster components. It employs a high pressure waterjet, operating typically at a pressure of 12-17,000 pounds per square inch, to slice through the thermal protection material and blow away the particles. It can also be regulated to strip the layers of paint and primer beneath the outer protective coating.

To prevent damage to the casing, hydroblast parameters—such as the angle of the waterjet to the workplace, water pressure and flow rate—must be precisely controlled. That cannot be done effectively by manual operation, which is also difficult, inefficient and dangerous to the operator. Waterjet control, therefore, is accomplished by a computer-directed six-degree-of-freedom robot mounted on a transportable platform; the platform has a watertight plexiglass-enclosed cabin that protects the robot controller and its two operators from heat, humidity and debris. This system typically takes

12 minutes to strip a booster segment where manual stripping took four to six hours.

The NASA/USBI technology has found new applications and a new company has been formed to pursue further development and commercial marketing. Still located at Huntsville, the USBI advanced technology group that developed the system has become Pratt & Whitney Waterjet Systems, a unit of Pratt & Whitney's Overhaul and Repair Operation (Pratt & Whitney, in turn, is a division of United Technologies Corporation, Hartford, Connecticut).

The system is now known as ARMS™, for Automated Robotic Maintenance Systems. Commercialization of the technology began in 1991, when the Air Force awarded Waterjet Systems (then USBI), a contract for a Large Aircraft Robotic Paint Stripping system employing waterjet technology (see page 87). Since then, Waterjet Systems has introduced a second commercial application of the technology, this one involving removal of coatings from jet engine components.

To protect them from the intensely hot and corrosive environment of an operating turbine engine, jet components such as vanes, combustion chambers, burner cans and turbine blades are coated with a variety of substances — aluminum oxide, boron nitrite, ceramics, magnesium zirconate and many others. The type of coating used depends on the component's job in the engine system.

When it is time for overhaul, the engine is disassembled and its parts stripped of these coatings. The customary way of doing this is by acid bath and grit blasting cleaning processes. These processes are highly labor intensive and they involve use of toxic stripping chemicals; workers must wear special protective clothing and a breathing apparatus to protect them from the fumes.

The ARMS system uses only minimal labor and does the component cleaning job significantly faster. For example, on a Pratt & Whitney demonstration, an engine compressor front assembly case was cleaned by an ARMS unit in an hour and a half, which compares with an average of 16 hours for manual cleaning of the same component. This provides a benefit in increased productivity by reducing the time it takes to strip, clean and return the parts to service. The system also extends the service life of the component, because waterjet stripping minimizes the amount of "substrate" (the part's surface) lost. And there is an environmental bonus in the reduction or elimination of the need for toxic chemicals, waste disposal and human protection equipment.

ARMS' equipment is contained in a soundproof, waterproof, enclosed workcell that includes the robot, a variety of nozzles and end effectors, a waterjet pump and a turntable. The part to be cleaned is mounted on the turntable, which rotates while the robot-controlled nozzle remains fixed; alternatively, the workpiece is held stationary while the robot moves over its surfaces. A computer controls the robot program; the location, position and speed of the turntable; and the water pressure and flow rate.

Early in 1992, Delta Air Lines became the first customer for an ARMS workcell. The unit was delivered in the summer of 1992 and by yearend Delta had completed acceptance testing and started engine component cleaning operations at its Atlanta (Georgia) Technical Operations Center. (Continued)

™ ARMS is a trademark of Pratt & Whitney Waterjet Systems

ROBOTS FOR AIRCRAFT MAINTENANCE
(CONTINUED)

Aircraft, civil and military, must periodically be repainted for protection of their surfaces. The biggest part of the job is getting the old paint off.

The most widely used method of removing the paint involves use of a methylene chloride-based chemical stripper. The chemicals are sprayed on, not just on wings and fuselage but on such areas as wheel wells, engine inlets and exhausts, and other hard-to-get-at places. The stripper is allowed to set for one to five hours, then washed off; in many cases, the stripper is reapplied and rinsed a second or third time. The job still requires finishing touches by putty knives, scrapers, brushes and sanders.

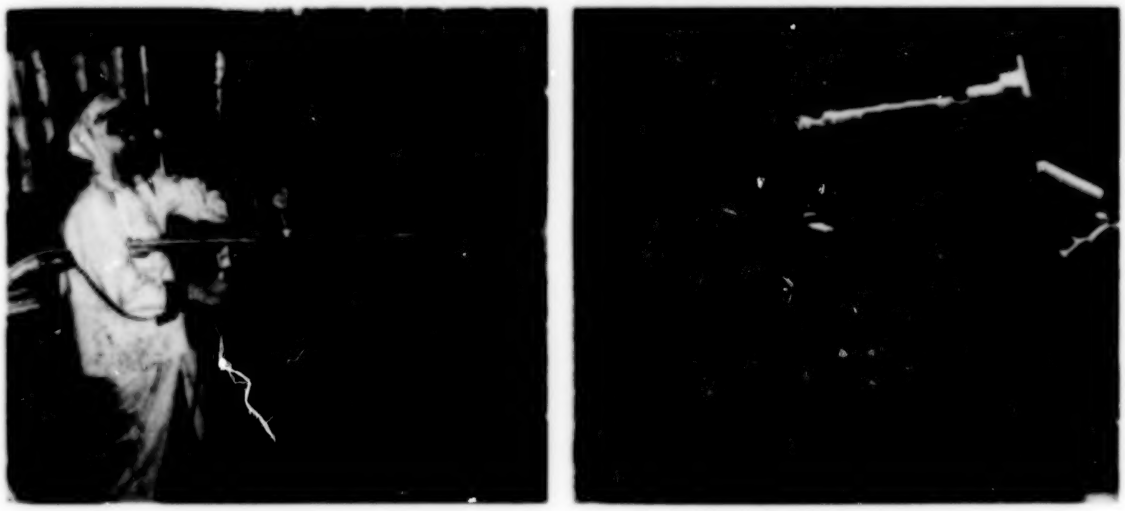
It's a time-consuming and increasingly costly job and it's getting more difficult with the advent of tougher environmental and occupational safety regulations, because chemical stripping poses problems of hazardous waste disposal, along with provision of protective clothing and equipment for maintenance workers.

Aircraft operators are looking for a better way to do the job and the U.S. Air Force is showing the way with a demonstration effort. The USAF's Oklahoma City Air Logistics Center, in conjunction with the Wright Laboratory Manufacturing Technology Directorate, Wright-Patterson Air Force Base, Ohio, has initiated a program to automate aircraft paint removal and eliminate methylene stripping by the year 2000.

In July 1991, the Air Force contracted with USBI Company, now Pratt & Whitney Waterjet Systems, for design and development of a Large Aircraft Robotic Paint Stripping (LARPS) system. LARPS is a cousin to Pratt & Whitney's ARMS commercial jet engine cleaning system; both spring from the waterjet stripping technology developed by USBI and Marshall Space Flight Center for removing paint and thermal protection equipment from space boosters (see pages 85-86).

LARPS is now well along in development and scheduled for 1995 installation at Oklahoma City Air Logistics Center, where it will be tested to verify the design and ultimately replace manual stripping on a variety of large aircraft.

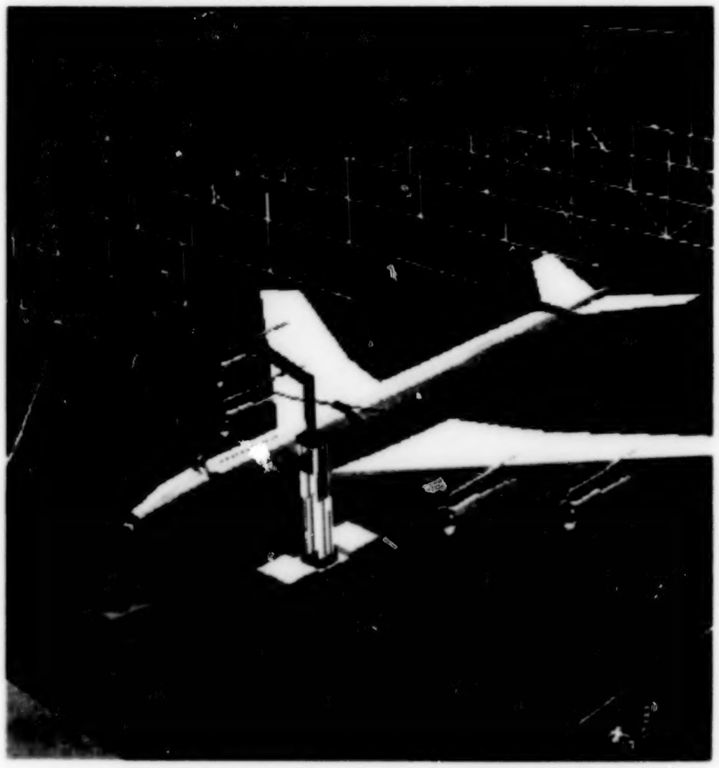
LARPS will consist of a robot arm mounted on a vertical column, which in turn is mounted on an automatically-guided transporter. The vertical column rotates on a turntable assembly located on the deck of the transporter. The robot arm moves up and down the column to reach various aircraft surface heights, and the transporter moves the robot from location to location following buried guidewires. The robot arm directs a high pressure jet of water or frozen carbon dioxide to strip the paint.



In the 1970s, NASA developed an automated system (far left) for removing thermal protection material from booster components. A spinoff of that technology is the ARMS system for cleaning jet engine components (near left).

computer-guided around the complex contours of the aircraft by input from a series of sensors. A computer subsystem controls the whole operation, supervised by a LARPS operator in a room adjacent to the work hanger.

Intended to reduce stripping time by 50 percent in comparison with the manual process, LARPS is designed to cut hazardous waste by 90 percent, eliminate personnel exposure to hazardous environments, and effect a significant reduction in stripping costs. For one specific airplane type, the Air Force estimates a 55 percent reduction of material costs, 43-49 percent savings in labor costs, and an overall cost reduction of more than 50 percent.



Now in development is a major advancement of the technology, the LARPS robotic paint removal system for use on military or civil aircraft. The prototype system shown here is scheduled for 1995 service at the Air Force's Oklahoma City Air Logistics Center.

Pratt & Whitney Waterjet Systems believes that LARPS has enormous potential in both military and civil aircraft maintenance. The company is working to extend the process certification to commercial jetliners, which offer a very broad international market; Pratt & Whitney is working with a special task force of the International Air Transport Association that is studying alternative techniques for aircraft paint stripping.

There is similar broad potential for the companion ARMS waterjet stripping system for jet engine components.

Use of the technology need not be confined to paint stripping. It could be adapted to aircraft painting, to improve aircraft surface paint quality and consistency and eliminate workers' exposure to flammability and solvent inhalation hazards. The technology also has potential in automating such aircraft inspection techniques as x-ray, ultrasonics, dye penetration, infrared or "CAT-scanning", to relieve workers of tedious repetitive tasks and generally improve inspection efficiency.

And there is additional potential beyond aircraft maintenance uses. Pratt & Whitney Waterjet Systems conducted an experimental test in which the technology was used to strip paint from an Army Hummer, and the company thinks its systems could be adapted to stripping such large objects as ships, railcars, military tanks and other combat vehicles.

Pratt & Whitney believes the waterjet technology will spawn a whole new industry and thereby eliminate a major use of toxic chemicals in the world marketplace. ●

Airline Operations Aid

Founded in 1988, American Airlines' Knowledge Systems is a group of software engineers who develop systems utilizing artificial intelligence technologies for such applications as aircraft maintenance, aircraft scheduling, fare administration, flight operations and computer operations.

The group employs a variety of knowledge based and expert systems tools, among them CLIPS (C Language Integrated Production System), a NASA-developed software package that was originally modeled on Inference Corporation's Automated Reasoning Tool. CLIPS was supplied to Knowledge Systems by NASA's Computer Software Management and Information Center (COSMIC)*, NASA's mechanism for helping industrial, government and institutional organizations to improve automation efficiency and cost-effectiveness.

CLIPS is used by Knowledge Systems for three purposes: as a rapid prototyping tool, to develop production prototypes, and to develop production applications. An example of the latter is CLIPS' use in the airline process known as "Hub SlAAshing", a knowledge based system that recommends contingency plans for American Airlines' System Operations Control (SOC) during inclement weather or other airport disruptions where severe schedule reductions must be made.

Prior to the introduction of Hub SlAAshing, SOC (***below***) used printouts of flight operations transactions to locate contingency plans manually, used colored markers to highlight candidate plans, weeded through the possibilities and ranked them manually. This labor intensive process has been automated by Hub SlAAshing, which integrates the CLIPS shell with more traditional technologies.

With Hub SlAAshing, the search for appropriate patterns is accomplished programmatically, saving time and allowing SOC coordinators to handle more difficult situations. Hub SlAAshing locates the candidates for schedule reductions and assimilates much of the information necessary to facilitate educated decision-making, thus minimizing the negative impact in situations where it is impossible to operate all flights. ●

NASA SOFTWARE IS CONTRIBUTING TO NEW EFFICIENCY IN AIRLINE SCHEDULING

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* COSMIC is a registered trademark of the National Aeronautics and Space Administration.

Human Factors Model

A SPINOFF SOFTWARE TOOL IS FINDING WIDE UTILITY AMONG INDUSTRIAL DESIGNERS

Shown below is Jack™, an advanced human factors software package available commercially for a broad range of computer-aided design applications. The product of more than a decade's research, Jack was developed by the Computer Graphics Research Laboratory of the University of Pennsylvania, with assistance by NASA and other government research agencies.

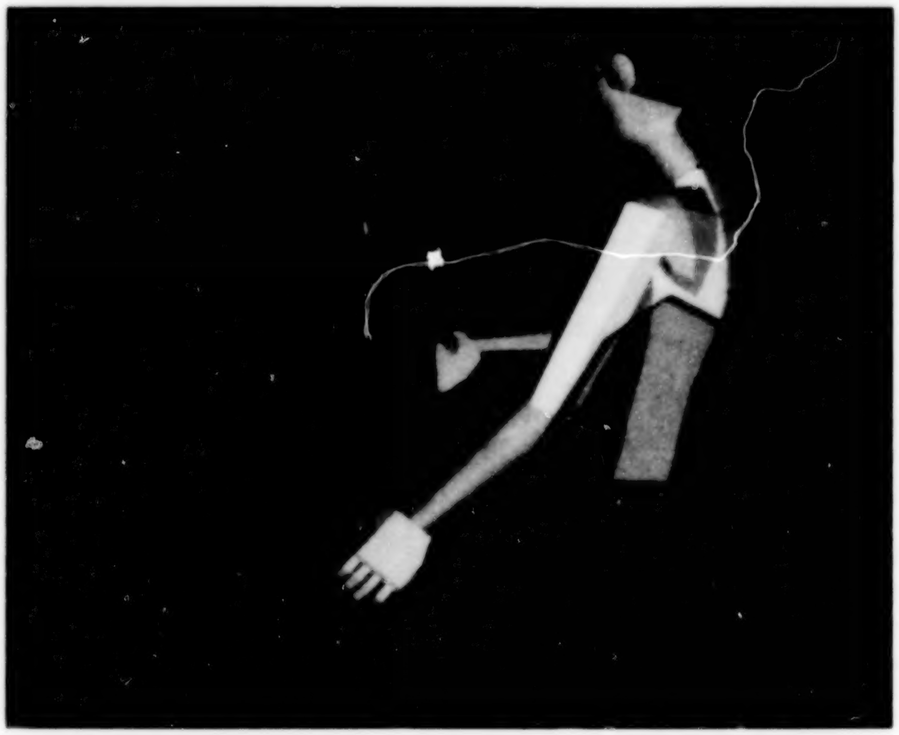
Jack is a visualization tool that provides a three dimensional model for predicting how a human will interact with a given system or environment, such as the helicopter cockpit design pictured. In this application, Jack helps a designer determine whether a human pilot would fit comfortably in the cockpit space provided, whether he would have an adequate field of vision, whether he could reach the controls, etc. Jack offers a number of unique features that can be useful not only to commercial and industrial equipment manufacturers but to architects and interior designers as well.

This marks the first time the University of Pennsylvania has directly marketed technology from any of its R&D projects. The program has already been used extensively in development and evaluation of Space Station *Freedom*, an Army helicopter and other military vehicles, and it played an important role in the human factors design of a new line of earthmoving equipment developed by Deere & Company. "With Jack," say its developers, "important ergonomic decisions are made at the workstation and considerable cost savings are realized over building and testing expensive prototypes."

The computer model's body consists of 39 segments, 38 joints and 88 degrees of freedom, including a 17-segment flexible torso. All parts are programmed to move automatically in response to commands, and a window on the screen shows the view as Jack sees it. Designers may configure as many models as necessary in an almost unlimited range of body proportions and abilities.

Johnson Space Center (JSC) was the original investor in the Jack development effort and JSC gave Jack its first real-world problems to solve. JSC functions as a co-researcher toward advancing computer modeling science, and the center provides data to the University of Pennsylvania for use in later versions of Jack.

Other supporters of the program include the Army Research Office and the Army Human Engineering Laboratory. Another contributor is Ames Research Center, which has incorporated Jack into a human factors system known as MIDAS (Man-machine Integrated Design and Analysis). ●



™ Jack is a trademark of the University of Pennsylvania.

Design Tool

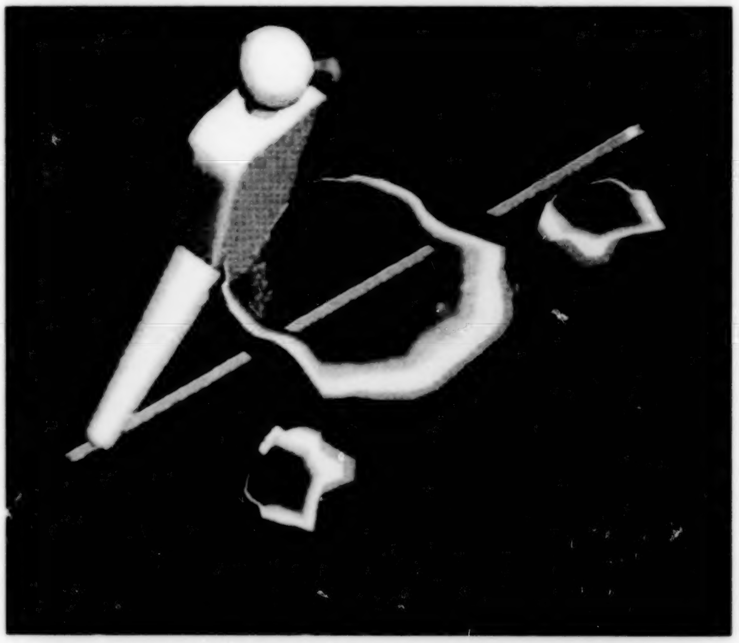
A SOFTWARE PACKAGE FOR FLOW COMPUTATION OFFERS A BROAD RANGE OF INDUSTRIAL APPLICATIONS

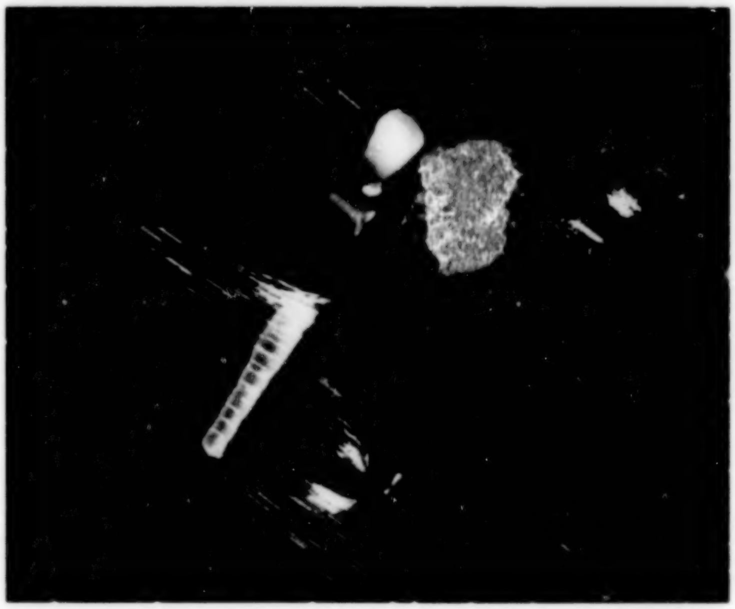
Under a Small Business Innovation Research (SBIR) contract with Lewis Research Center, Fluent Inc., Lebanon, New Hampshire developed a CFD (Computational Fluid Dynamics) software package for computing the flow around very complex shapes, such as aircraft contours.

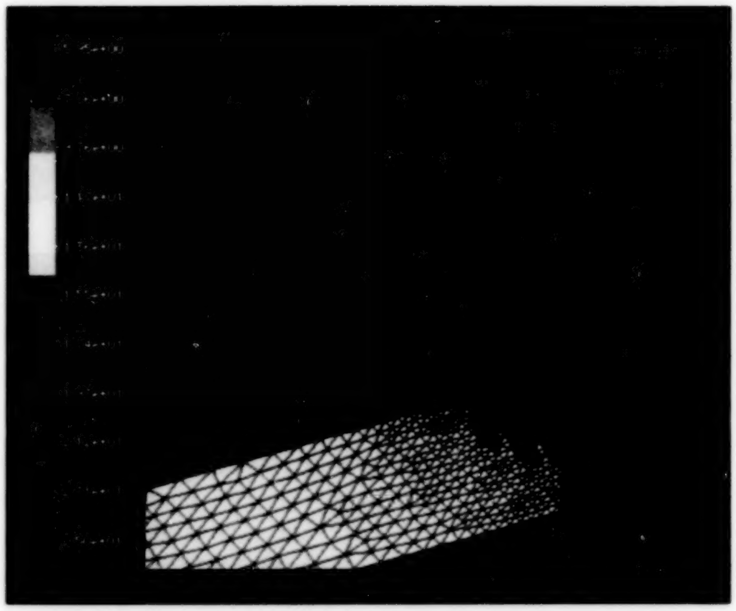
Developed by Fluent's Dr. Wayne A. Smith, the CFD code has evolved into a commercial product known as RAMPANT™, which is available on an annual lease basis.

Dr. Smith started work on the SBIR project in 1987 with the goal of producing a CFD code that was flexible, fast and easy to use. To get flexibility, he used an innovative unstructured grid approach. RAMPANT uses tetrahedral (four-sided) cells to divide the flow field into discrete pieces instead of the six-sided cells used in more traditional CFD codes. This approach provides greater flexibility than the structured grid approach because it does not impose a fixed order on the layout of computational cells. RAMPANT also offers reduced cost of using CFD through a multigrid technique for getting flow solutions in minimal computer time.

RAMPANT, says Dr. Smith, "is well suited for any problem that involves fluid flow and heat transfer around or inside complex geometries." The code's versatility was demonstrated in 1992 when it was employed to compute the flow of air around a Nordic ski jumper. Many of the jumpers in a competition had switched to a new jumping technique called "V-style", a term that describes the shape the skis form while flying through the air with the ski tips spread far apart. Fluent made a comparison of the flow over a V-style jumper (***upper left***) and a traditional jumper with parallel skis (***lower left***). RAMPANT's results showed that the longer distances V-style jumpers were getting was due to differences in aerodynamics caused by the change in ski positions.







RAMPANT, Smith adds, "is especially applicable to fluid flow problems in the aerospace, automotive and turbomachinery industries."

An example of an aerospace application that is easily handled by RAMPANT but would be difficult to compute under the traditional structured grid approach is prediction of the flow over an airfoil with leading edge and trailing edge flaps. Knowledge of the characteristics of this flow is essential to designing wings with greater lift, which allow lower (hence safer) speeds for aircraft landings and takeoffs. RAMPANT is able to predict accurately the maximum lift produced by airfoils with multiple flaps.

In the automotive industry, RAMPANT can compute the external aerodynamics of cars, trucks, motorcycles, underhood and passenger compartment flows, and the flow through various engine components. ***At left*** is a RAMPANT computation of the vortices (air whirlpools) shed behind a moving auto of simple shape.

In the turbomachinery industry, RAMPANT can predict the flow through axial and centrifugal turbines, inlet and exhaust ducts, and auxiliary cooling passages. The image ***below left*** shows the pressure contours on the surface of an axial flow compressor that was tested at Lewis Research Center. ●

™ RAMPANT is a trademark of Fluent Inc.

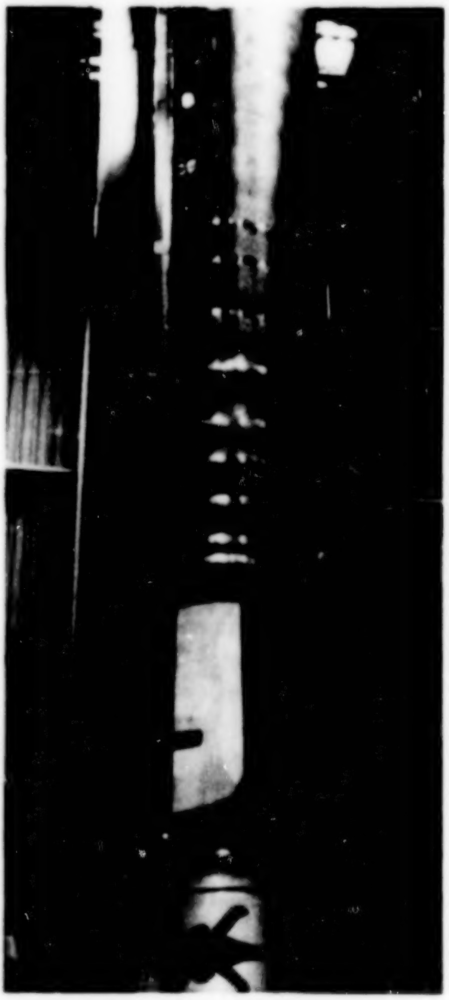
Helicopter Strakes

A NASA AERODYNAMIC INNOVATION SOLVES A PROBLEM OF HELICOPTER FLIGHT

In hovering or low speed flight, a single rotor helicopter experiences significant aerodynamic loads, or downward pressuring forces, on the fuselage and tail assembly. This is due to combinations of wind, maneuvers and downwash from the main rotor. The download is offset by increasing the thrust of the main rotor and the tail rotor, but that costs a penalty in payload or performance.

In the late 1980s and early 1990s, Langley Research Center sought a way to correct this problem and focused on the concept of using strakes on a helicopter's tail boom. A strake is a "spoiler" whose purpose is to alter the airflow around an aerodynamic body to get some kind of benefit. In this case, the intent was to change beneficially the loading on the tail boom of a single rotor helicopter, which can experience limitation of tail rotor power and directional control when it is flying sideward to the right or hovering in wind coming from the right (main rotor torque accentuates the drag force effect in right sideward flight).

Langley conducted wind tunnel experiments with strakes of different sizes mounted at various locations on representative tail boom models of several helicopter types, measuring the forces on the boom under a variety of wind speed and flight conditions. These tests were followed up by flight testing of a strake-equipped helicopter at NASA's Wallops (Virginia) Flight Facility.



Langley's research demonstrated that properly placed strakes mounted on a tail boom change the air loading, reduce the thrust and power requirements of a tail rotor, and provide an economical way to improve helicopter low speed flight handling qualities, particularly in right sideward flight. The center's work led to incorporation of tail boom strakes on three production-type commercial helicopters.

One of the three is the MD520N, introduced to service in 1992, which was developed by McDonnell Douglas Helicopter Company, Mesa, Arizona. The MD520N is an innovative helicopter that has no tail rotor. A tail rotor is normally employed to offset the twisting moment—known as torque—created by a helicopter's main rotor. Torque tends to make the aircraft turn in a direction opposite to the main rotor's rotation. The tail-rotor is an anti-torque device; it prevents the tendency to turn and thus provides directional control.

In place of the tail rotor, the MD520N has a NOTAR™ (No Tail Rotor) anti-torque system in which "sheets" of air are ejected through slots on the right side of the tail boom; this air deflects the wake of the main rotor around the tail boom and produces an aerodynamic side force. In hover and low speed flight, this side force provides 60 percent of the required anti-torque moment needed to balance the torque generated by the main rotor. The slotted, air ejecting

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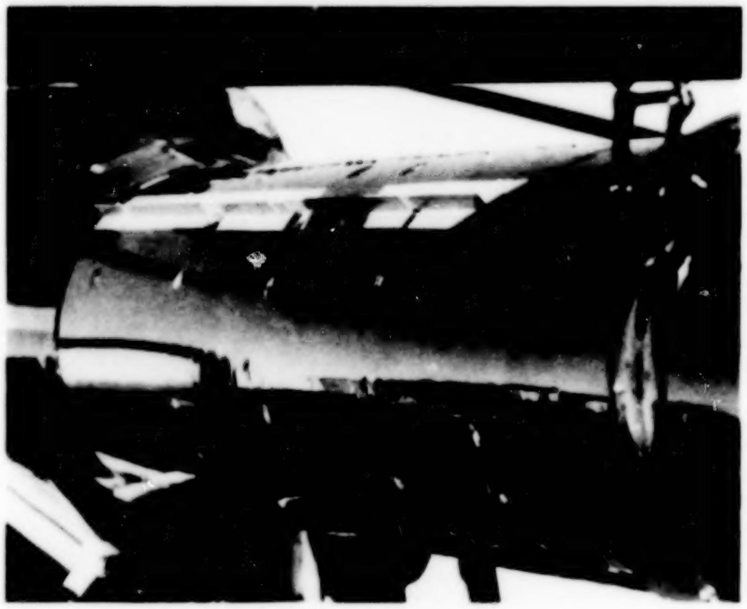
tail boom is known as a "circulation control" boom.

In developing the MD520N, McDonnell Douglas Helicopter Company conducted an extensive research effort aimed at enhancing the performance of the circulation control type of tail boom. The company made use of much of the conceptual and testing information provided by Langley Research Center's investigation into the effectiveness of tail boom strakes on conventional tail rotor helicopters. McDonnell Douglas' work focused on determining the strake location at which tail boom anti-torque force is greatest and tail boom download is least for the circulation control NOTAR helicopter.

The research started with wind tunnel tests of model tail booms and proceeded to full scale wind tunnel testing of the NOTAR tail boom. ***At left***, a strake-equipped tail boom is mounted vertically in the company's open jet wind tunnel; wind blows from a jet nozzle at right over the tail boom, then exits through a collector at left. ***Above***, the experimental MD520N is undergoing sideward flight test with an instrumented tail boom and strake at the company's Mesa facility. ***At right*** is a closeup of the tail boom with a strake (white area) optimized for height, length and location on the basis of flight test data; what seem like blemishes on the shiny surface are pressure instrumentation ports for measurement of aerodynamic forces. The research led to the incorporation of strakes on MD520N production models; the strake is very light (less than two pounds), simple in design and easily integrated in the helicopters. ●



™ NOTAR is a trademark of McDonnell Douglas Helicopter Company.

Motorcycle Parts

A NASA PUBLICATION

HELPS A SMALL

BUSINESS IMPROVE

ITS MANUFACTURING

PROCESS

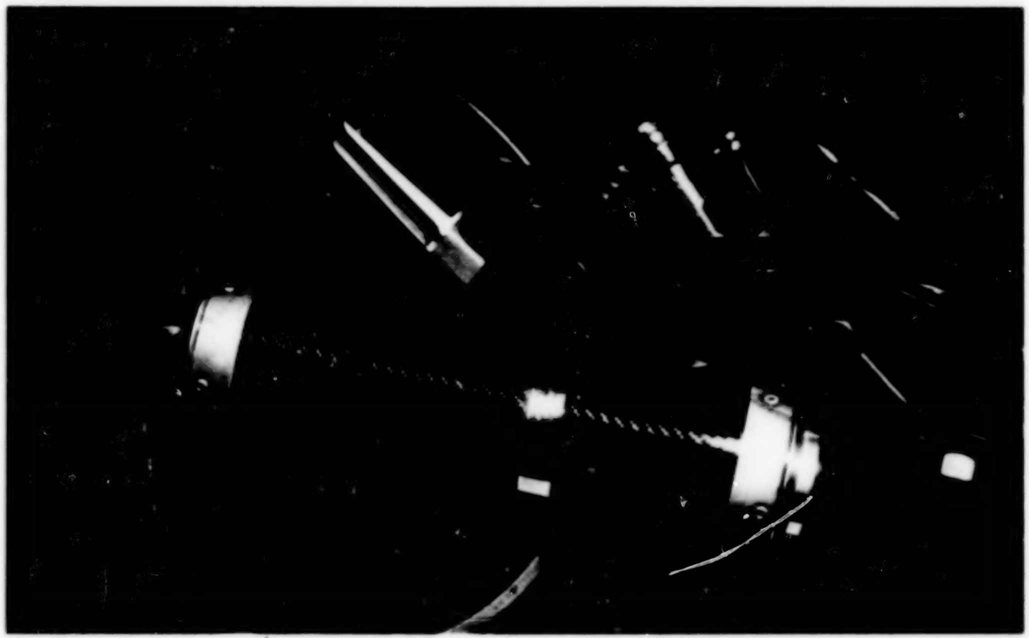
NASA Tech Briefs is a monthly publication used as a problem solving tool by more than 200,000 government and industry readers (see page 141). Each issue reports on newly developed products/processes and on innovative technologies originating in NASA research. Readers interested in adapting a particular innovation to their own purposes can get more detailed information from NASA by requesting a Technical Support Package (TSP).

Tech Briefs has become a prime source of spinoff applications. An indication that the publication's information is being widely employed is the fact that NASA annually fills some 135,000 requests for TSPs.

Sometimes it happens that the information supplied in a *Tech Briefs* article is by itself sufficient to generate a spinoff application without need for the TSP. An example is the experience of a small firm — Performance Extremes R&D, Norman, Oklahoma — producing motorcycle parts. It is a particularly interesting example because none of the three partners in the company is an engineer and, as president Larry Ortega admits, "many of the articles in *NASA Tech Briefs* are over our heads." Nonetheless, the group was able to use the information in one *Tech Briefs* article to substantially improve their manufacturing process for motorcycle parts.

The company was started on the idea of making motorcycle parts out of carbon/epoxy to reduce part weight. "Our first attempts were pitiful," Ortega reports. A friend introduced him to *NASA Tech Briefs*, specifically an article that detailed a vacuum bagging process for forming composite parts. At that point, no one in Performance Extremes had heard of vacuum bagging, but they bought a vacuum pump the next day and started using the process described in *Tech Briefs*. ***At left***, Ortega is "prepping" a part; it is placed in a vacuum bag, drawn under vacuum with a pump, then heat-cured in a radiant oven.

"Using vacuum bags, our parts came out with a better surface and far fewer voids inside," Ortega says. "But we still had a problem; parts were warping after cooling." The epoxy being used did not respond well to heating lamps; uneven heating caused spots to deform upon cooling. The group went to the University of Oklahoma library and scanned back issues of *Tech Briefs* looking for an answer — and they found one: a researcher had discovered that a metal plate inside the vacuum bag made for more even heat transfer.



They tried it using a one-eighth-inch thick copper plate in the vacuum bag. After curing under the same heat lamps and the same processing conditions, the cooled part was perfect.

"We still use a vacuum bag with a copper sheet to cure prototype parts," says Ortega. "There has been no problem."

At left are the components of a typical part, various layers of material which are cut and placed in a mold; a similarly-shaped piece of copper is placed over the assembled composite to ensure even heat distribution. ***Above*** is an example of a finished Performance Extremes part, a muffler installed on a motorcycle, and ***at right*** is a sampling of parts and some of the materials from which they are made.

Performance Extremes found another useful technique in *Tech Briefs*. Ortega explains: "We work on a number of motorcycles and have found that over time the multiple wire connectors come loose. Replacing a multiple connector takes a lot of man-hours and is not always a sure cure. We went back to *Tech Briefs* and started digging."

And again they got an answer. A *Tech Briefs* article described a simple procedure for repairing loose connector pins rather than replacing them: use of a hypodermic needle to inject epoxy into a fault connection; when the epoxy dries, there is no play in the wire. Performance Extremes is now using that technique to advantage.

Larry Ortega no longer has to go to the university for his *Tech Briefs* research; he is now a subscriber and an appreciative one who says, "When we need technical information, *Tech Briefs* is the first source we turn to." ●

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FIGHTING FOREST FIRES

In the spring of 1993, the Department of Agriculture's U.S. Forest Service (USFS) introduced to operational use a new airborne system for imaging forest fires. Known as Firefly, it provides major advances in informational accuracy and timeliness — and therefore gives USFS firefighters a valuable tool for fire containment.

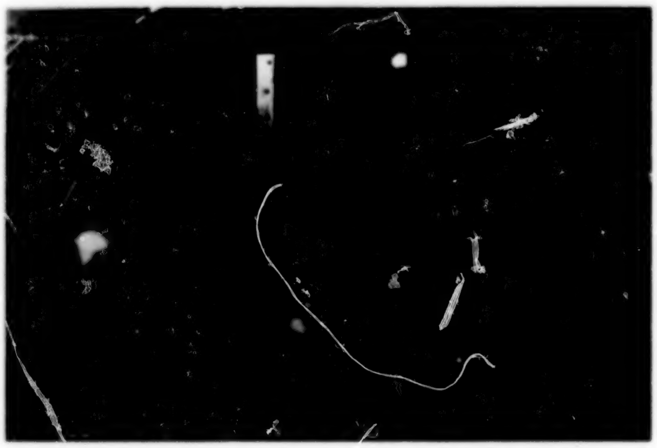
The system was developed by Jet Propulsion Laboratory (JPL) in collaboration with USFS. It draws upon NASA remote sensing technology and JPL's 25 years of experience in developing digital image processing techniques for enhancing spacecraft pictures of distant planets. USFS handled development of the associated ground terminal and air-to-ground digital communications link.

Firefly is an outgrowth of a previous JPL/USFS collaboration that spawned FLAME, an airborne fire mapping instrument that has been in service with USFS since 1984. Firefly employs advanced technology to provide two significant advancements over its predecessor: it uses satellite-based navigation to get greater positioning accuracy, and it offers increased timeliness of fire location data delivery by means of on board data processing and a direct aircraft-to-fire camp communications link.

AMONG TECHNOLOGY TRANSFERS THAT ENHANCE PUBLIC SAFETY IS A SYSTEM DESIGNED TO IMPROVE WILDLAND FIRE MANAGEMENT

Firefly and FLAME are similar in many respects. Both use an infrared line scanner to identify fire boundaries. FLAME, however, employs standard navigation methods to fix the position of a fire location on a map, and its imagery is captured on film; the plane must be landed and the film delivered to an interpreter, who performs a lengthy hand-transfer of the data to a map. As much as eight hours may elapse between fire spotting and getting the information to a firefighting camp.

The new Firefly is a near-real time system capable of processing the remotely-sensed data on board the aircraft and delivering location-plotted fire maps to a fire camp within 30 minutes. The system consists of the airborne unit, which includes a special purpose dual band infrared sensor for locating forest fire perimeters and "hot spots" (small fires), together with a ground terminal at the fire camp linked to the airborne unit by telemetry. The airborne infrared sensor system penetrates smoke to image the ground scene, correlates fire data to geographic coordinates, and transmits fire imagery and processed data directly to USFS' portable field computer at the fire camp. Precise determination of the location relative to a geographic base is made possible by use of the Global Positioning System, a Department of Defense-operated network of satellites



At right is an image of a California forest fire produced by an airborne remote sensing system known as Firefly (the black areas represent the highest temperatures). At left below is the Firefly system mounted in the U.S. Forest Service's Merlin III fire mapping airplane. The system transmits fire location information directly to a fire camp, affording valuable time saving.

that allows fixing an airplane's position — in three dimensions — within 25 to 100 meters.

Among the biggest problems in combating forest fires are 1) the fires are very difficult to pinpoint and 2) they can spread very rapidly. Firefly offers help in both areas.

"Cutting the turnaround time in getting information to the firefighters is the key," says Dr. J. David Nichols, JPL's manager of the Firefly project. "We gain time in two ways: processing the data and mapping the location information in the airborne computer, then communicating directly, computer-to-computer, with the plotting system on the ground."

Time is vital to wildland firefighters, particularly in pinpointing hot spots, small areas of high intensity flame that flare up outside the boundary of a fire and threaten to become separate large fires. If they are detected quickly enough, the USFS fire incident commander can assign people to them and extinguish them before they become full-fledged fires.

In operation, the Firefly-equipped airplane is flown over the site of a known existing fire or an area where fire activity is suspected. The infrared sensor detects radiation from the fire and converts the radiation values into electrical signals. Signal processing produces an image identifying the perimeter of an established fire or the location of a high intensity hot spot; the system is capable of mapping an area as large as 250 square miles each hour or, from an altitude of 10,000 feet, detecting a hot spot no bigger than half a square foot. Firefly is controlled by an airborne unit operator who monitors the system's performance and relays information to the pilot to optimize the airplane's flight path; he also has the capability to append messages to the data being sent to the fire camp based on his observations of the raw infrared imagery.

JPL will continue to refine the Firefly technology on the basis of its initial operational experience. Additionally, NASA and the USFS are jointly exploring other ways in which advanced aerospace technology can benefit wildland firefighting. ●

Storm Warning Service

A COMMERCIAL WEATHER ADVISORY SERVICE EVOLVED FROM NASA'S COLLABORATION WITH A TV METEOROLOGIST

At right, Bob Baron of Baron Services, Inc., Huntsville, Alabama is monitoring a weather display, part of a severe weather advisory service he provides on a commercial basis. Baron Services is a spinoff company whose weather advisories are based on data originating at Marshall Space Flight Center (MSFC), also located in Huntsville.

In 1988, Bob Baron, chief meteorologist of Huntsville's NBC affiliate WAFF-TV, learned that MSFC had developed a lightning detection and location network that provides real time information. Intended as an aid to NASA research operations at MSFC, the Marshall system uses a central processor to collect raw data from strategically placed antennas in Alabama and Tennessee; the data is transmitted to users by telephone lines.

Baron proposed and concluded an arrangement with MSFC whereby the center would provide him the data and he would refine and enhance the MSFC real-time display software. He formed Baron Services to commercialize the system and acquired his first two clients, Huntsville Utilities and the Huntsville division of space rocket manufacturer Thiokol Inc.

A 1989 tornado that caused extensive damage in the Huntsville area prompted Baron to modify his service to allow quicker and more accurate dissemination of severe weather information to the public. Baron Services developed a means of changing the computer data to audio data for transmission by radio station subcarrier, reception by clients through an antenna, and decoding by computer for display.

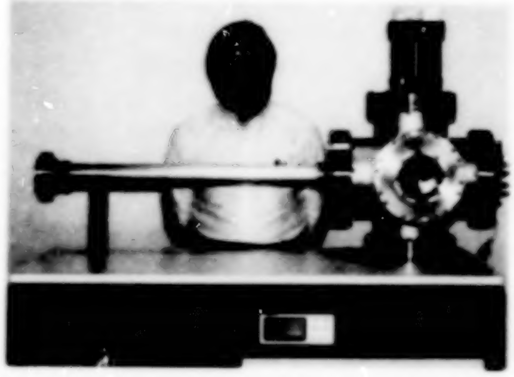
In 1991-92, Baron further improved the service. He developed software to combine on-screen data from the Lightning Detection Service with a conventional weather display showing clouds and rain intensity. Later, he advanced the system to combine real time lightning data with Doppler radar, broadening the range of storm data and enabling client companies to monitor the approach and departure of significant storms and schedule their operations accordingly.

The latest development is storm projection, which gives utilities, emergency management officials and others affected the ability to plot a dangerous storm's projected movement, instantly identify all communities in the storm's path, and estimate the time the storm will arrive at each community.

Baron Services' client list has expanded considerably and the company is now expanding into several other locations. Baron has entered into a joint agreement with Enterprise Electronics Co., Enterprise, Alabama, a Doppler radar manufacturer, and Geomet Data Service, Tucson, Arizona, a national lightning detection concern, to continue development of the service and market it nationally and internationally. ●

Material Testing Device

SMALL BUSINESS RESEARCH CONTRACTS YIELD ADVANCED COMMERCIAL INSTRUMENTS



At right is a FAST™ system for testing the effects of the space environment on spacecraft and space systems materials. Shown in the photo is Robert H. Krech of Physical Sciences Inc. (PSI), Andover, Massachusetts, co-inventor of the system with PSI president George E. Caledonia.

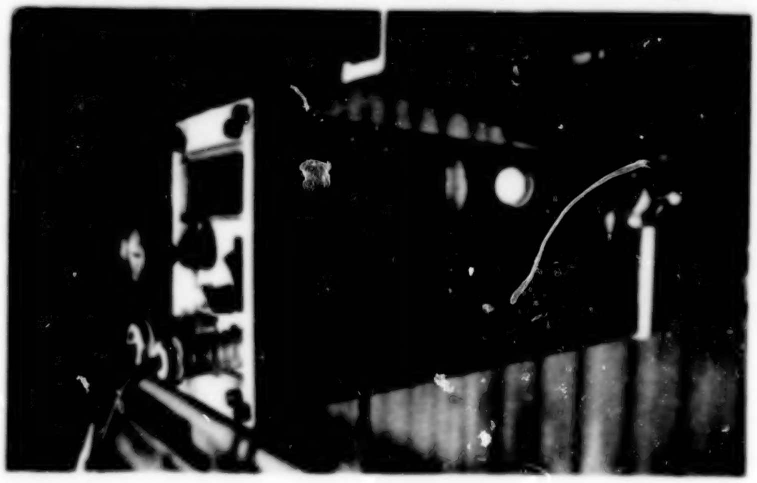
The FAST (Fast Atom Sample Tester) device simulates in a vacuum chamber how some materials react to contact with atomic oxygen and degrade under long term exposure. The system was developed for NASA as a means of performing accelerated erosion testing of spacecraft materials in a simulated low Earth orbit environment.

Developed under a Small Business Innovation Research (SBIR) contract with Jet Propulsion Laboratory, FAST has become a source of commercial business for PSI. The system is being sold commercially for use in aging certification of materials intended for orbital operation. Investigations are under way for application to etching in submicron printed circuitry and thin film coating.

A second SBIR contract with JPL yielded another commercial spinoff product, the Optical Temperature Monitor (OTM) introduced in 1992. The OTM (*below*) is a multi-wavelength pyrometer designed for precise measurement of high temperatures (between 700 and 2500 degrees Centigrade) on materials that have poorly known emissive properties or emissive properties that change with time or temperature. This instrument was developed originally for application to materials manufacture in space but, with additional funding from PSI and the National Science Foundation, the measurement techniques that evolved from the NASA-sponsored research were extended to development of a commercial instrument for measuring and controlling flue gas temperatures in utility and industrial boilers — thus offering potential for increasing the thermal efficiency and availability of energy producing facilities worldwide.

With modification, the OTM instrument could find further application in waste destruction and in energy intensive manufacturing operations such as steel, glass, cement, petrochemical, pulp and paper processing. The broad promise of the OTM prompted PSI to create a new company — PSI Environmental Instruments Corporation — for manufacture and marketing of the system.

PSI also offers an Aerospace Measurement Service to support research, test and advanced development projects conducted by aerospace industry firms. This service also involves NASA technology transfer, since much of the testing capability was developed in the course of two NASA SBIR contacts, one with Lewis Research Center and one with Marshall Space Flight Center. ●



™ FAST is a trademark of Physical Sciences Inc.

Industrial Inspection System

A SPINOFF X-RAY SYSTEM FROM AN EARLIER ERA IS STILL FINDING NEW APPLICATIONS

B*elow*, an operator is watching the video monitor of the new LIXI® Conveyor x-ray system to spot defects in the products being inspected. The installation pictured is in the processing plant of a company offering a totally boneless chicken product. Manufactured by Lixi, Inc., Downers Grove, Illinois, the LIXI Conveyor has a high resolution imaging system that can distinguish small bone fragments in the chicken (***right***), allowing immediate rejection of the defective package.

An important feature of the system is its ability to inspect 100 percent of the product right on the production line, not in a quality control laboratory. The LIXI Conveyor is synchronized with standard line speed; packages enter a totally sealed and waterproof x-ray chamber and a real time image is presented on the monitor. The system can detect defects measuring less than a millimeter.

The system can be configured with various options to suit different products and applications. It is designed to accommodate products up to 18 inches in length that might have defects not easy to distinguish from surrounding non-defective areas. Among examples of applications are food products, medical devices, printed circuit boards, electronic components and small parts.

The LIXI Conveyor, produced by Lixi, Inc. under NASA license, is the latest in a long line of spinoff devices that trace their origins to a portable x-ray instrument developed in the late 1970s by Goddard Space

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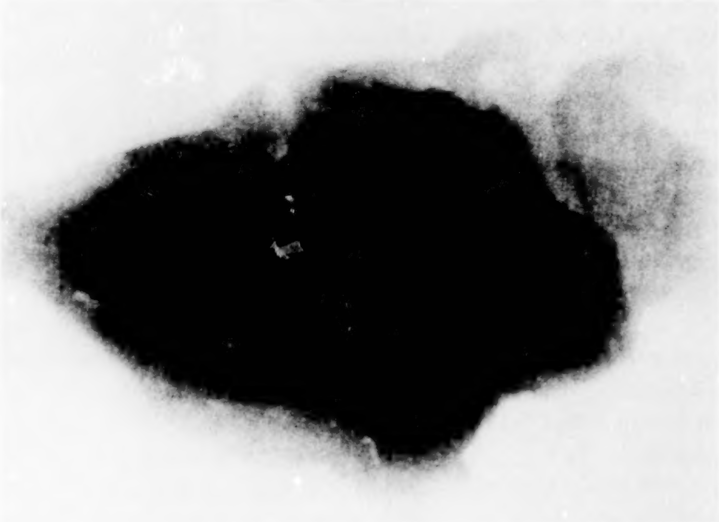
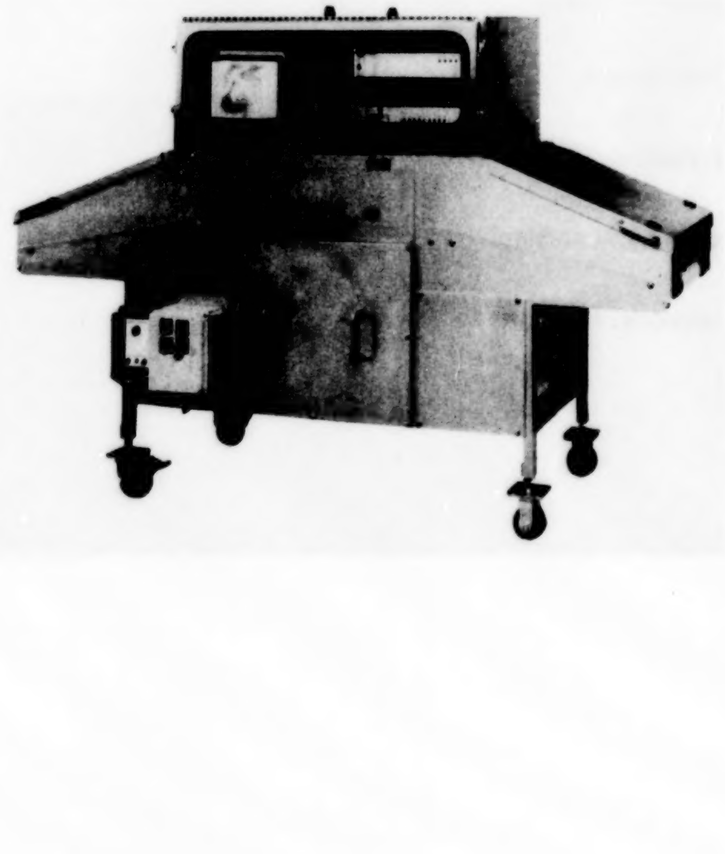


Flight Center. Called the Low Intensity X-ray Imaging Scope, it was designed to use less than one percent of the radiation required by conventional x-ray devices. That feature, plus its portability, made it attractive for a broad variety of industrial and medical applications.



Lixi, Inc. has used the NASA technology to build a thriving business serving a growing list of U.S. and international customers. The company manufactures certain standard systems, but it is primarily a systems integration firm developing a variety of custom configurations employing x-ray technology as the core component and including such other technologies as image enhancement, videography, thermal printing, materials handling, computers and software. Lixi produces a number of types of industrial inspection systems; hand-held and portable units for security applications; and battery-powered hand-held x-ray devices for medical use in remote areas of the Third World. ●

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* LIXI is a registered trademark of Lixi, Inc.

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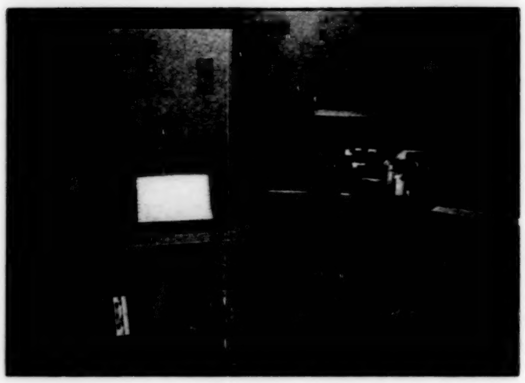
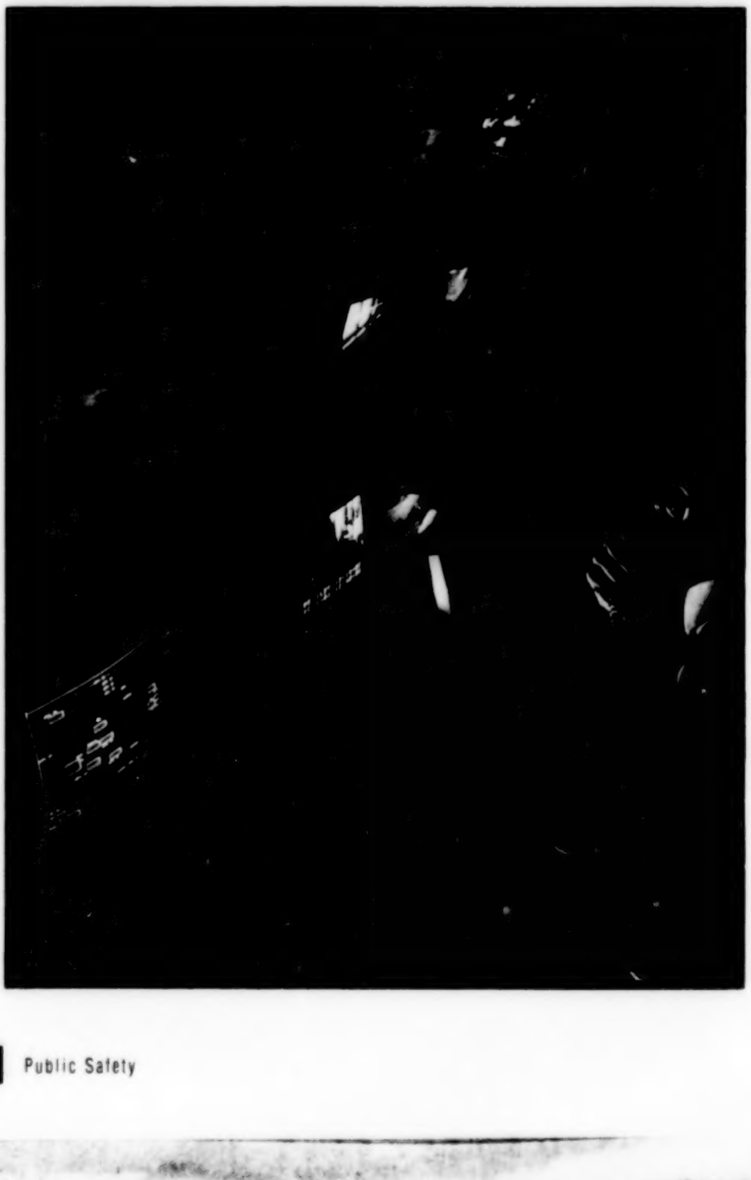
Security System Software

A NASA SOFTWARE TOOL IS A KEY ELEMENT OF A COMMERCIAL SECURITY MANAGEMENT SYSTEM

Software House, Waltham, Massachusetts manufactures physical security systems for a wide range of government and business users (***below***). These systems include many types of security devices, such as card validation, alarm monitoring, closed circuit TV, video badging and biometric identification systems.

Software House's primary security management system is the C•CURESystem 1 Plus™; The photo ***at right*** shows the C•CURESystem 1 Plus family of products. The software based system may be used with a variety of access control hardware at installations ranging from individual or remote locations to multiple integrated networks around the world. Advanced software programs enable C•CURESystem 1 Plus users to manage large amounts of information and to solve unique security problems; they also provide power over access control with time schedules, authorization levels, door entry with card validation, and extensive reporting capabilities.





In addition, C•CURESystem 1 Plus provides access to other information management tools, such as the NASA expert development tool named CLIPS. Using CLIPS, Software House integrates software and hardware to solve problems that might arise with the various access control systems. The expert system software prototype asks a series of questions about what the hardware is doing or not doing; from the given answers, the program makes recommendations on possible routes to check and what might be causing the problem. CLIPS enabled Software House to develop new generations of hardware that allow problem solution by a non-expert person with fast response.

CLIPS was developed by Johnson Space Center and was supplied to Software House by the Computer Software Management and Information Center (COSMIC)®, a NASA-sponsored mechanism for making available at nominal cost government-developed computer programs that have secondary applicability (see page 140). ●

™ C•CURESystem 1 Plus is a trademark of Software House.

® COSMIC is a registered trademark of the National Aeronautics and Space Administration.

Robotic Hand

SPACE-USE ROBOTIC SYSTEMS BECOME COMMERCIAL PRODUCTS

Shown below is the Omni-Hand, a robotic hand for which its developers claim "capabilities virtually identical to those of the human hand." The multiple digit hand features an opposable thumb and a flexible wrist. Electric muscles, called Minnacs™, power wrist joints and the completely interchangeable digits.

The Omni-Hand was developed by Ross-Hime Designs, Inc., Minneapolis, Minnesota for Marshall Space Flight Center under a NASA Small Business Innovation Research (SBIR) contract. Two Omni-Hands have been delivered to NASA for evaluation and potential use on space missions. The unit is also commercially available for such applications as hazardous materials handling and manufacturing automation.

Ross-Hime Designs had earlier developed for NASA, under SBIR contracts with Langley Research Center, systems known as Omni-Wrist™ and Omni-Wrist II that are also commercially available for such applications as spray painting, sealing, ultrasonic testing and a variety of nuclear industry, aerospace and military use.

A relatively new company formed in 1987, Ross-Hime has patented a number of robotic mechanisms with humanlike "singularity-free" motion (singularity is a phenomenon of robotics that can cause a joint to jam as it attempts to move in an area where it has no axis of rotation or range of motion). The company has conducted development programs under four SBIR contracts. In addition to Omni-Hand and Omni-Wrist, its robotic products include a Dextrous Arm and the Minnac electric muscle. ●

™ Omni-Wrist and Minnac are trademarks of Ross-Hime Designs, Inc.

Risk Assessment System

A SOFTWARE SYSTEM FOR NASA RISK EVALUATION PROVIDED A BASIS FOR A NEW FAMILY OF SPINOFF SOFTWARE TOOLS

With today's complex systems, there is increasing need for tools that provide quality analysis and help management track the intricate process of risk assessment. To that end Lockheed Engineering and Sciences Company developed, under company funding, a software system for evaluating risks; the system was subsequently enhanced under NASA funding and it became known as FEAT, for Failure Environment Analysis Tool. FEAT uses directed graph — or digraph — models to provide information on cause and effect if a set of failure events occurs.

FEAT served as the basis for a family of spinoff software tools based on digraph model methodology developed by DiGraphics, Inc., Houston, Texas. The company's "flagship" product is the Diquest Analyzer, which uses digraph models to answer two questions about system failures: What happens to a system if a particular event happens? And what are the possible causes of the event?

The digraph model uses circles and arrows to indicate the propagation of failure effects throughout a system, capturing all the failure interactions within and between subsystems. A particular failure event is chosen via a "point and shoot" graphic interface. The results are displayed on a color highlighted schematic familiar to the user.

As a design tool, the Diquest Analyzer helps reviewers understand what redundancies have been built into a system and where weaknesses need to be protected or designed out.

DiGraphics was founded in 1991 by James Miller, original designer of the FEAT technology as a Lockheed employee; Mike Austin, senior programmer for FEAT during its Lockheed/NASA evolution; and John Reed, who brought extensive marketing experience to the team. In the ***accompanying photo***, Miller is at right, Austin at left and Reed in the center.

They introduced the Diquest Analyzer in 1992, with initial focus on safety organizations in the chemical industry for risk assessment, design evaluation and change management. More recently, the technology has found application in operations monitoring, diagnostics and training of new personnel. ●

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Testing Services

NASA TECHNICAL INFORMATION HELPED IMPROVE THE SERVICE TECHNIQUES OF A TESTING LABORATORY

Trace Laboratories is a full service independent testing laboratory specializing in the testing of printed circuit boards, automotive products and military hardware. The company maintains two separate facilities in Chicago, Illinois and Linthicum, Maryland to serve U.S. customers.

Trace Laboratories-Central in Chicago is one of many U.S. firms that have benefited from technical information contained in *NASA Tech Briefs*, a publication designed to advise industry of recent technological advances and technologies available for transfer (see page 141).

Jeffry A. Schutt, general manager of Trace Laboratories-Central, reports that his division used two *Tech Briefs* articles, plus follow-up Technical Support Packages from Jet Propulsion Laboratory, to enhance the company's testing process. Specifically, NASA information on "electromigration" was applied to the surface insulation resistance (SIR) testing that Trace Laboratories frequently conducts on printed circuit board materials, such as fluxes and solder pastes (***below*** a Trace technician is assessing the integrity of a prepared test pattern prior to subjecting it to testing). The NASA input helped optimize the SIR testing process without compromising testing data and it allowed Trace to reduce testing time.

This is important because SIR testing evaluates the effects on electronic materials that have been cleaned by an alternative method to the use of chlorofluorocarbon (CFC) solvents, which electronics manufacturers have used for years to clean components; they are seeking to eliminate CFC solvents, which are soon to be banned. SIR test data on the durability of parts is used by manufacturers to refine their production processes.

Says Jeffry Schutt, "The Technical Support Packages from NASA reaffirmed much of what we already knew about electromigration but also opened our eyes to other issues that needed to be considered. The information enabled us to improve the quality of the service we provide our customers." ●

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VIRTUAL REALITY: YOU ARE THERE

Telepresence is an emerging technology of broad potential. The term means that, with the help of advanced technology devices, a person may figuratively project himself into another environment, say, for example, the surface of a distant planet being explored by a robot; the telepresent person sees exactly what the robot sees with a sense of actually being there, and he can control the robot's movements although he is millions of miles distant.

Telerobotic control of automated systems in space is not yet a reality, but it is a NASA goal considered entirely feasible. Telepresence, to a limited degree, is a reality — or, to use the scientist's term, a "virtual reality."

Although the technology is still at the "ground floor" level, systems that permit a human operator to "virtually" explore a computer-generated artificial environment — and interact with it — are routinely being demonstrated in both government and business applications. The key component of the technology — 3D computer graphics — is already in wide commercial use and expanding explosively.

A FAMILY OF TELEPRESENCE SYSTEMS HEADS A SELECTION OF SPINOFFS IN THE FIELD OF COMPUTER TECHNOLOGY

A world leader in virtual reality/telepresence research is Ames Research Center, which is exploring future uses of the technology and at the same time actively employing it in current applications. For example, Ames' Numerical Aerodynamic Simulation Facility is using virtual reality devices to add an extra dimension to the science of computational fluid dynamics. In an aircraft design effort, for instance, a virtual reality system allows a NASA scientist, wearing an electronic glove, to "enter" the virtual wind tunnel, release a smoke tracer and observe at first hand the smoke flow around the aircraft model.

A basic system Ames employs is a stereoscopic display presented on two small screens, one for each eye; the display may be an artificial environment generated by a computer or a real environment relayed from remote video cameras and converted to computer compatibility. With an electronic glove, the operator can interact with the computer environment; he might, for example, grasp an object within the simulation, a chair perhaps, and move it — and the computer will accordingly move the chair in the display. Taking it a step further, one can don a sensor-equipped suit that makes possible full-body interaction with the computer-generated virtual world.

Several telepresence systems manufacturers are taking this technology into the commercial world. One of them is Fakespace, Inc., Menlo Park, California, a spinoff company that got its start as an Ames contractor for development of a teleoperated motion platform for transmitting sounds and images from remote locations. The system, known as Molly™, pans, tilts and rolls in real time, matching the head motion of the user; coupled with a stereo viewing device and appropriate software, it creates the experience of telepresence, or "being there."

At right, an Ames Research Center engineer is viewing a computer simulation of the complex airflow around a Space Shuttle Orbiter model, using a stereoscopic viewing instrument known as BOOM2C; with the electronic glove on his right hand, he can "enter" and interact with the virtual reality display.

Fakespace used the NASA technology as a springboard for development of a family of systems that produce what the company calls "practical immersive technologies" — systems that generate a full range of the sights and sounds of a virtual world without the need for suits, gloves, headphones and other sensors usually employed in virtual reality presentations. The reduced requirement for accessory equipment opens up a new range of commercial applications.

Fakespace's companion piece to Molly is the BOOM™ (Binocular Omni-Orientation Monitor). Either system can be used alone. Together they comprise a complete telepresence system; Molly delivers sights and sounds from a remote location, the BOOM is the user's viewing device that provides the sense of being part of the virtual environment.

The BOOM is a counterbalanced stereoscopic viewer perfectly balanced on a six-jointed arm with a six-foot reach. The user holds the viewer by a handle and peers into the eyepieces, which are small CRTs — one for each eye — displaying the 3D virtual environment created by the computer.

Fakespace offers a basic high resolution BOOM2 model that provides monochrome views and an "extreme resolution" BOOM2C™ model that can be switched between a color mode and a monochrome mode.

In addition to NASA, Fakespace's growing list of customers includes such widely known organizations as Sandia National Laboratories, Stanford Research Institute, Mattel Toys and the National Center for Supercomputer Applications. Among initial applications are the earlier described computer-aided design technique, which can be employed in many industries, and virtual reality visualizations in scientific and architectural work.

A unique application that underlines the broad potential of the technology is one in use by Japan's Matsushita company, which has a vast display of lighting fixtures in a huge warehouse; a customer can virtually walk the aisles of the warehouse and inspect the whole inventory of lighting fixtures without ever leaving the comfort of an armchair in the front office. ●

™ Molly, BOOM and BOOM2C are trademarks of Fakespace, Inc.

Seminar Software

A NASA SOFTWARE SYSTEM AIDS SEMINARS ON COMPUTER SIMULATION

The Society for Computer Simulation International (SCS), San Diego, California is a professional level technical society dedicated to distributing information on the methodology, techniques and uses of computer simulation.

A major SCS goal is technical interchange among government, industry and academia. To that end, SCS holds frequent conferences and seminars on the latest technological areas wherein simulation is emerging as a significant tool in research, development or testing.

A useful aid employed in a series of professional seminars by Mary Lou Padgett, SCS vice president for North America, is a NASA program called NETS (Neural Network Development Tool). Developed by Johnson Space Center, NETS is a software system modeled after the human brain; it is designed to help scientists exploring artificial intelligence to solve problems that involve pattern matching.

The seminars, intended for professional people who are familiar with neural networks to varying degrees, promote technology transfer and encourage those interested in applications to use neural networks like NETS. Padgett gives participants examples that they can manipulate, alter or enhance for their own applications. Padgett, at right in the photo ***below***, is shown conducting a seminar on NETS usage.

NETS was supplied to Padgett by NASA's Computer Software Management and Information Center (COSMIC)*, which makes available to businesses and other organizations, at relatively low cost, government-developed computer programs that have secondary applicability (see page 140). ●

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* COSMIC is a registered trademark of the National Aeronautics and Space Administration.

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Advanced Keyboard

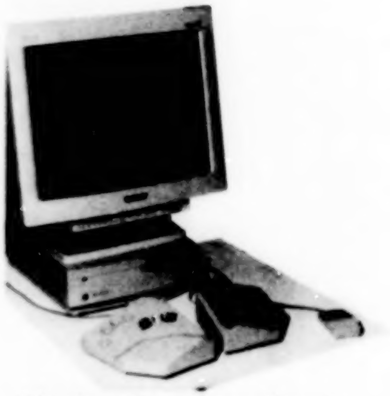
A SPINOFF COMPUTER KEYBOARD OFFERS IMPROVED JOB ACCESS FOR DISABLED WORKERS

Infogrip, Inc., Baton Rouge, Louisiana has introduced the BAT™ chord keyboard for computer data entry as an alternative to standard computer keyboards, a system that offers special utility to disabled people but also provides advantages to the general population of computer operators.

The BAT employs chordic technology, in which operators finger key combinations — like striking a chord on a piano — for text or graphics input. Designed for single-hand use, the BAT has only seven keys compared with 101 on the standard (QWERTY) keyboard. Five of the keys are positioned directly under the thumb and fingers; the other two are positioned so that the thumb can easily reach them with a slight movement to the left or right. By pressing a combination of keys, the BAT user can enter anything that can be entered by the traditional keyboard. Users can also program additional words or phrases commonly used in their specific applications.

Because it can be operated with a single hand without moving the hand between rows of keys, the BAT offers the possibility of improved job access for workers with disabilities such as amputation, paralysis and impaired vision (the BAT chord system is based on Braille).

Infogrip cites a number of advantages for the general population of keyboard users: the operator need not look at the keyboard; one-handed use frees the other hand for moving a mouse (***below***), flipping through documents or holding a phone; the unit's ergonomic design reduces the strain and fatigue commonly associated with prolonged use of traditional keyboards; and a proficient operator can make inputs faster. For even faster input, Infogrip offers a two-unit system, one BAT for each hand (***above***).



The BAT chord keyboard, says Infogrip, is "easier to learn than touch typing and the basic chords can be learned in about an hour."

The chordic input technology was developed jointly by Infogrip and Stennis Space Center, with test and evaluation assistance by Mississippi State University. NASA is interested in the potential of chordic technology for speeding human interaction with flight computers on board aircraft or spacecraft, and additionally in creating a low cost tactile/visual training system for the handicapped. ●

™ BAT is a trademark of Infogrip, Inc.

Industrial Inspection System

AN AEROSPACE IMAGING SYSTEM IS SERVING GENERAL INDUSTRY AS A DEFECT DETECTOR

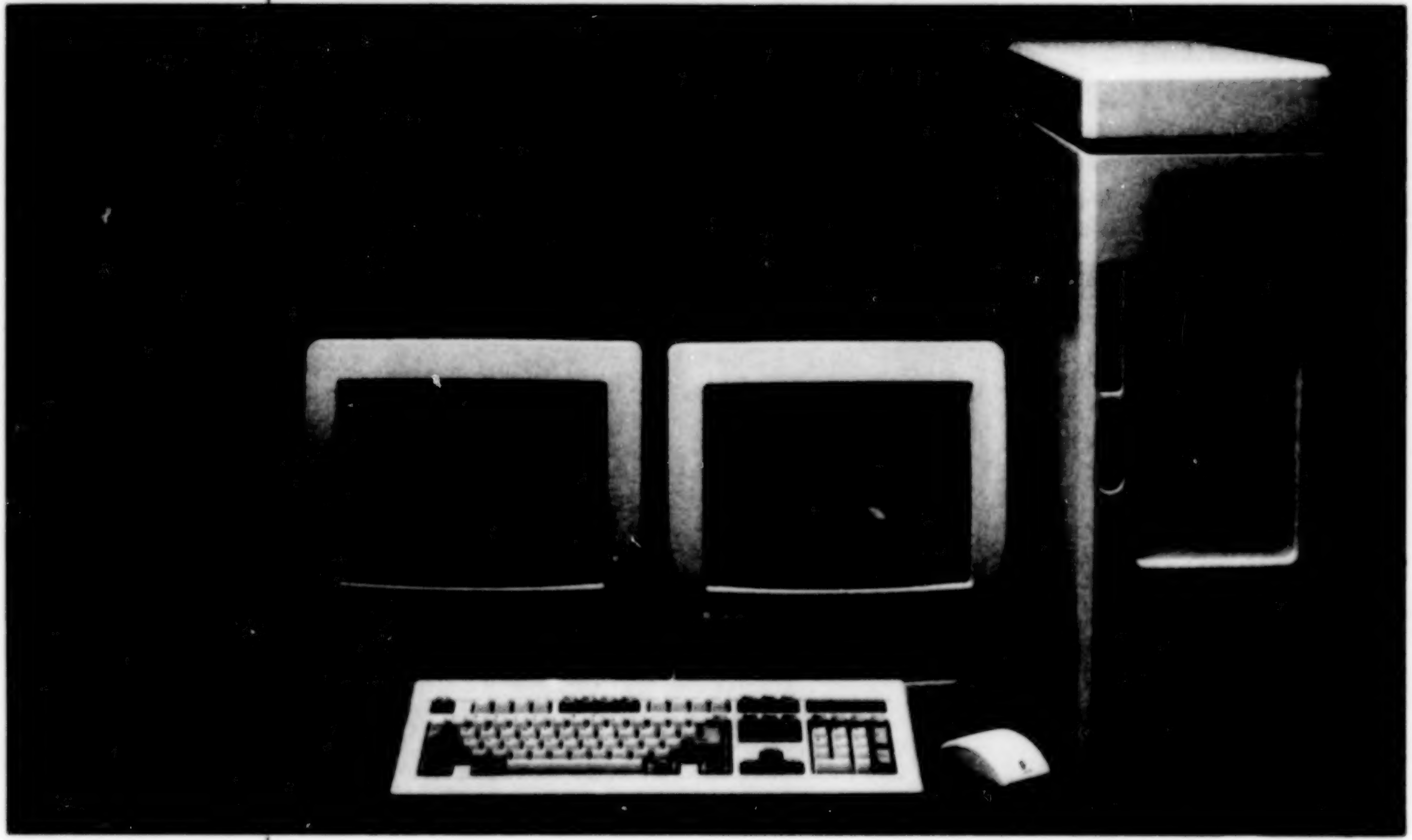
For Marshall Space Flight Center (MSFC), BIR Inc., Lincolnshire, Illinois developed an industrial inspection system that employs computed tomography (CT) technology to find imperfections in aerospace structures and components, such as castings, assemblies, rocket motors and nozzles.

Known as ACTIS, for Advanced Computed Tomography Inspection System, it has been in service at MSFC since 1989 and commercial units have been sold to aerospace manufacturers. Now BIR (Bio-Imaging Research) has refined the technology and introduced for general industrial use a smaller, PC version called ACTIS+ which, the company says, can "provide CT imaging capability at less than one-tenth the cost of current industrial CT systems."

CT is an aerospace spinoff technology known to millions of Americans who have undergone the medical body-scanning diagnostic technique known as CATscanning, which incorporates digital image processing technology that originated in NASA research and development as a prelude to the Apollo moon landings. The technology is also in wide industrial use, principally in the field of non-destructive testing.

The key to the low cost of ACTIS+ is that it is designed to be added to an existing RTR (real time radiography) system; it uses major RTR components and eliminates the expense of an x-ray system, detector system and radiation-safe site modification.

ACTIS+ is pictured ***below***. The components include, from left, a high precision rotation/elevation manipulator; a color image monitor; a graphical user interface monitor with keyboard and mouse; and the Unix-based PC compatible workstation that houses the electronics for data acquisition, image



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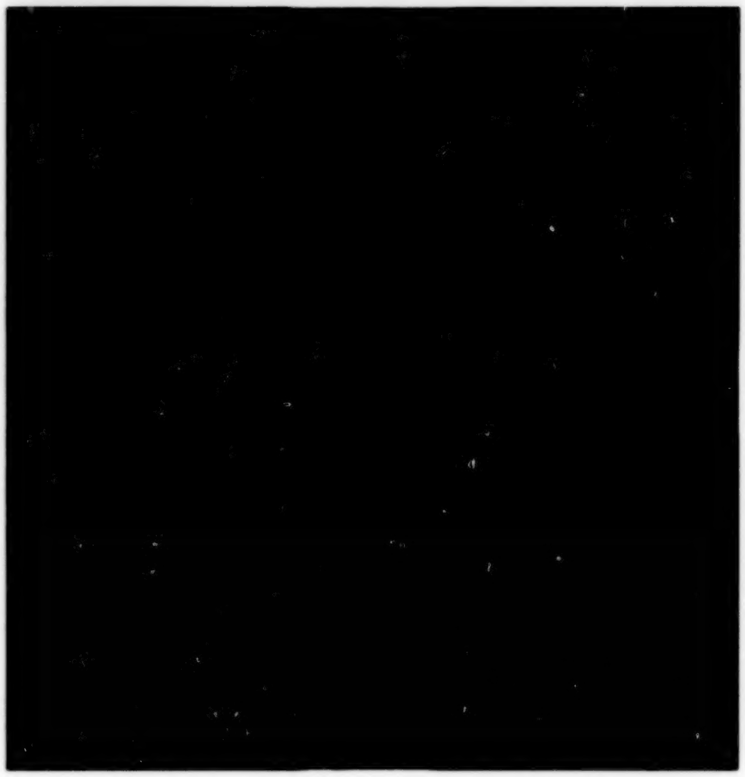

processing and motion control.

ACTIS+ can generate "cross-sectional CT images that enhance inspection capabilities by providing detail not found in projection radiographic images," according to BIR. Company literature lists some examples of how CT can improve the manufacturing process:

"Find internal defects in parts before machining and processing; monitor the effects of process changes on product quality; verify assembly before a product is put into service; make dimensional measurements and transfer to computer-aided design/computer-aided manufacturing; locate reinforcements in structural composites; identify potential product safety and liability problems; and generate or correct computer-aided design data."

Above is an ACTIS+ image of an ordinary pencil showing the detail in the graphite core (purple) and the glue joints between sections of wood.

Below is an image of a two-inch aluminum casting in which a hairline crack is identified in the lower right portion of the image.

The high speed scanning feature of ACTIS+ — scanning and image reconstruction in less than one minute — offers the capability for 100 percent inspection in a production environment. ●

Small Business Innovations

NASA SMALL BUSINESS RESEARCH PROJECTS YIELD ADVANCED SOFTWARE SPINOFFS

A steadily growing source of aerospace spinoff applications is the Small Business Innovation Research (SBIR) program, which was established by the Congress in 1982 with dual objectives: to increase participation by small businesses in federal R&D activities, and to stimulate conversion of government-funded research into commercial applications.

NASA is one of 11 major technology-generating agencies of the federal government participating, each administering its own program independently under policy guidelines set by the Small Business Administration. In the decade-plus since the program's inception, NASA has awarded SBIR contracts to more than 800 companies and commercial spinoffs have resulted from about one of every three projects completed.

Among recent examples of successful commercialization in the field of computer technology is the introduction of an advanced family of software products developed by Symbiotics, Inc., Cambridge, Massachusetts under SBIR grants from NASA and the U.S. Army.

Under the Army grant, Symbiotics developed a cornerstone software system that permits users to upgrade their products from standalone, isolated applications so that they can communicate and participate in a distributed computing environment. NASA's Kennedy Space Center (KSC) is applying the software to its continuing problem of integrating new technology with existing systems — for example, integrating newly-developed artificial intelligence systems into the computer complex of the Space Shuttle launch processing system, which has equipment that in some cases is more than 20 years old.

Under a subsequent NASA SBIR grant, Symbiotics extended the original technology to include additional tools, grouped under the product name SOCIAL, that enable NASA to integrate and coordinate the intelligent and conventional systems used to plan and schedule Shuttle launch support operations. SOCIAL provides an object-oriented distributed processing environment that lets users pass

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data among applications in a network of computers with different processors, architectures and operating systems — even when the applications are written in different programming languages. In the photo at left, the array of computer systems illustrates the ability of Symbiotics' program Networks to network various platforms. ***At left*** is the company's vice president-marketing, Duncan MacKay, talking with Richard Adler (center), vice president of advanced development.

Symbiotics introduced SOCIAL as a commercial product in 1993. "SOCIAL has applicability in a broad variety of government and commercial domains," says Dr. Richard Adler, Symbiotics' director of advanced development. "For example, manufacturing process control closely resembles KSC's operations support for the Space Shuttle fleet: a computer network is used to monitor and control equipment, such as the equipment for producing chemicals, semiconductors or mechanical parts. Other parallels include operation support for complex communications, computer, power generation/distribution and transportation networks. In the business sector, SOCIAL can be used to integrate networks of financial workstations, their resident databases, analysis and graphic display tools."

Another SBIR program that spawned a commercial product involves the work of Software Productivity Solutions, Inc. (SPS), Indialantic, Florida in developing tools for software reuse, an emerging technology that can, says SPS, "produce software of significantly higher quality at a lower cost and in less time."

SPS conducted separate SBIR projects for Langley Research Center and the Army, developing systems for reusing existing software rather than creating new computer programs from scratch. The technologies from both projects were combined in SPS' commercially available Information Library System known as InQuisiX™.

InQuisiX is a reuse library providing high performance classification (***above***), cataloguing, searching, browsing, retrieval and synthesis capabilities that form the foundation for comprehensive automation reuse. With InQuisiX, says company literature, "software assets once thought to be obsolete can be identified for use in new applications."

InQuisiX provides a technological base for SPS' plan to develop a broad line of products for the commercial market. SPS has formed a business alliance with Science Applications International Corporation (SAIC), San Diego, California for marketing software reuse products and services. SPS will be responsible primarily for development and commercialization of advanced software. SAIC will focus on providing analysis and consulting services. ●

™ InQuisiX is a trademark of Software Productivity Solutions, Inc.

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Scheduling Software

SPACE SHUTTLE SOFTWARE BECOMES A SCHEDULING TOOL FOR MANUFACTURING INDUSTRIES

Avyx, Inc., Englewood, Colorado has introduced a new software product — called ASE™, for Advanced Scheduling Environment — designed to provide "scheduling solutions" for complex manufacturing environments. ASE is an evolutionary development based on a resources management software system originally developed for NASA use in such activities as scheduling Space Shuttle flights and satellite activities.

Avyx describes ASE as "a powerful suite of software modules for the modeling and solution of complex scheduling problems." It is primarily applicable to process manufacturing scheduling situations, but it can be applied to any other environment where competing objectives contend for limited resources. ASE, says the company, offers problem solving capability for manufacturers and such other organizations as hospitals, telephone companies, airlines or utilities that schedule large crew and equipment pools for repair and maintenance services.

ASE's utility is illustrated by the case history of BFGoodrich facilities in Santa Fe Springs, California, where the company makes carbon disc brakes for heavy aircraft. The manufacturing process involves multiple steps and the number of alternatives for assigning manufacturing resources is large. It is particularly difficult to schedule use of chemical vapor deposition (CVD) furnaces used to produce brakes of different sizes. BFGoodrich was able to handle the scheduling task with a manual system until a large influx of orders required operation at full capacity. Then it became obvious that the manual system could not keep up with new demands for schedule changes. Major rescheduling took as long as two weeks. The cost to Goodrich was underutilization of the expensive CVD furnaces.

Goodrich adapted an ASE-based Avyx Scheduling Solution designed specifically for the disc brake processing operation. Through use of the ASE software, the plant is now able to schedule more accurately the exact processes required for any part in current or future production. Use of expensive assets, such as CVD furnaces and machine tools, has been optimized. Avyx reports: "The financial returns, from both improved throughput and higher equipment utilization, resulted in operational cost savings in the first year greater than the investment required to install the Avyx system."

Other Avyx clients in the tobacco and paper industries have reported similar experiences.

Both the ASE product and Avyx, Inc. owe their existence to aerospace technology transfer. Avyx is an offshoot of a company formed in 1981 to provide computer-related services to NASA and other government agencies. The initial commercial product — called TREES-pls — was a software tool for more efficient management of resources — people, machines, dollars — by industry. TREES-pls became the programming language module for the ASE system and Avyx has expanded the "tool kit" with the addition of other modules. ●

™ ASE is a trademark of Avyx, Inc.

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Reliability Prediction

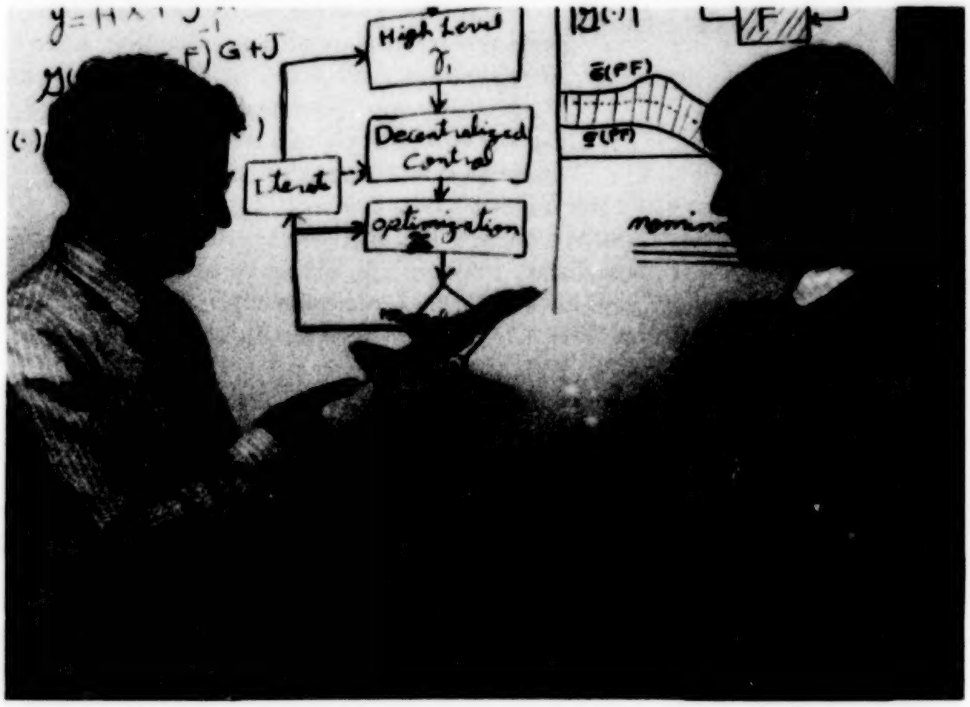
A SPECIAL NASA SERVICE OFFERS GOVERNMENT-DEVELOPED COMPUTER PROGRAMS TO INDUSTRY

***B**elow*, engineers Elaine Sears (at right) and Dr. Abbas Emami-Naeini of Systems Control Technology, Inc. (SCT), Palo Alto, California are working on an aircraft performance assessment. SCT is a company that provides research and development services in support of government contracts.

SCT's clients include a number of aerospace industry firms engaged in such government-sponsored projects as mission planning, flight simulation, aircraft and avionics research, air traffic control and commercial software development. Among other services SCT develops software tools for use in concurrent design and engineering.

An example of an SCT project is research on vehicle subsystem integrity, which involves performance predictions of such subsystems as landing gear for jet aircraft. In this type of work, SCT uses a software package known as RELAV (Reliability and Availability Analysis), which was developed by Jet Propulsion Laboratory and supplied to SCT by the Computer Software Management and Information Center (COSMIC). COSMIC is NASA's mechanism for making available to industry and government users computer programs developed by government agencies that have secondary applicability.

RELAV contributes to SCT's research by providing a system level evaluation of a technology. SCT assesses systems — such as the mechanism of a landing gear — by first describing it as a set of components operating together to perform a specific function. Each of the components has a specific probability relating to performance, which together form a system probability. RELAV uses the subsystem and total system probabilities to predict the availability of the system in terms of the probability of success. RELAV can also calculate a system's reliability for a specific mission. SCT can then translate this information into operational support requirements and minimal maintenance-free periods of operation. ●



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THE FERROFLUIDS STORY

Environmental standards for American industry are getting tougher and tougher. Among recent control measures imposed by the Environmental Protection Agency (EPA) is one that limits the allowable amount of "fugitive emissions" escaping into the atmosphere from petroleum refining and chemical processing facilities, primarily volatile organic compounds, or VOCs.

This is a new Ferrofluidics Corporation exclusion seal that promises enormous improvement in controlling "fugitive emissions" that escape from industrial equipment; the seal is a spinoff product of a fast-growing company that is itself a spinoff founded on space technology.

Compliance with these new regulations is a special headache for oil chemical plants whose process pumps move liquid petroleum and byproducts 24 hours a day. These pumps use mechanical seals to block emissions but the seals inherently allow some vapor emissions. A further problem is the fact that some regional authorities have accelerated implementation of the EPA mandates. So industrial firms are looking for a cost-effective sealing solution that will not only enable compliance with current rules but will meet the tighter emission requirements on the near horizon.

Ferrofluidics Corporation, Nashua, New Hampshire says it has the answer to the problem: a pump sealing system in which a primary mechanical seal works in tandem with a secondary Ferrofluidic® seal. Ferrofluids are magnetic liquids that do not exist in nature. Man-made substances that originated in space technology, they are fluids in which microscopic metal particles have been suspended, allowing the liquid to be controlled by a magnetic force.

In the various Ferrofluid exclusion seals, permanent magnets create a magnetic field in the air gap between the housing and the rotating shaft of a process pump. Ferrofluid is inserted into the gap and held precisely in place by magnetic force, creating a perfect hermetic seal that stops the escape of gas and vapor from the mechanical seal.

A NEAR PERFECT SEAL OF ENORMOUS POTENTIAL IS REPRESENTATIVE OF SPINOFF ADVANCES IN INDUSTRIAL PRODUCTIVITY AND MANUFACTURING TECHNOLOGY

"We believe our environmental sealing systems, which are specifically configured to combat fugitive emissions, can reduce the leakage to one part in a million," says Alvan F. Chorney, president of Ferrofluidics' Components Group. "The EPA considers 'zero leakage' anything less than 50 parts per million."

The Ferrofluidic sealing system is the product of a three-year cooperative design and development effort on the part of Ferrofluidics; Chevron USA Products Company, one of the largest U.S. refiners and marketers of petroleum products; and BW/IP International, a major supplier of seal and pump products.

Beginning in 1991, the environmental seal underwent extensive field testing at a Chevron refinery against a particular VOC known as light naphtha flush. Testing has since been expanded to include a variety of other emissions at a number of refinery and chemical processing facilities, among them plants operated by DuPont, Shell, Unocal, Amoco and Texaco.

Since its commercial introduction in January 1993, the sealing system has won endorsement from many leading industrial companies. Ferrofluidics and BW/IP are optimistic about business prospects in the refinery, chemical, pharmaceutical and paper industries.

The Ferrofluidics story is one of the real classics in the annals of aerospace technology transfer, a tale of how an apparently unproductive NASA research program generated a spinoff technology that an imaginative entrepreneur built into a thriving, multimillion dollar business.

It started in the early days of the space program when Lewis Research Center was looking for a way to feed weightless liquid fuel into the engine of an orbiting spacecraft. A Lewis scientist hit upon the idea of magnetizing the fuel by dispersing within it finely ground particles of iron oxide; the fuel could then be drawn into the engine by magnetic force. But about that time the rapid advance of solid rocket technology put the magnetic fluid concept on the shelf.

The concept surfaced again a few years later at Avco Space Systems Division as a possible means of controlling the temperature of an orbiting spacecraft. Again it was shelved in favor of another solution. But two Avco scientists — Dr. Ronald Moskowitz and Dr. Ronald Rosensweig — saw great potential in ferrofluids. After advancing the earlier research to a commercially viable level, they formed Ferrofluidics Corporation in 1968. Moskowitz has remained with the company since its inception; he is now chairman of the board and chief executive officer.

The early years were lean ones as the small company focused on R&D and sought commercial applications. It found an initial use in a zero leakage non-wearing seal for the rotating shaft of a system for making semiconductor chips. The seal solved a persistent problem — contamination due to leaking seals — and sparked widespread interest in the technology.

Since then Ferrofluidics' product line has expanded in big leaps. The principal revenue generators are its rotary feedthrough seals for the semiconductor industry. The company additionally produces sealing systems for other contamination-sensitive applications, such as computer disc drives, halogen lamps and medical x-ray equipment. Other products include hydrodynamic bearings, a high-performance alternative to mechanical bearings; inertial dampers for such applications as plotters, printers, optical scanners, machine tools and medical equipment; fully automated crystal growing systems; and fluids for home and automotive loudspeakers.

The spinoff company built on an obscure space concept is now the world's leader in ferrofluid technology. It has grown from a tiny firm that had $65,000 in sales in its first year into a $30 million a year company with subsidiaries in Europe, Japan and Taiwan; an investment in biotechnology; and a collaborative venture with International Jensen in ferrofluid-based noise cancellation technology.

But the best is yet to come, Ferrofluidics officials feel. Their unique technology is regularly finding new applications and the company is ranked among the "IB 100" — International Business magazine's list of the 100 fastest-growing U.S. firms. A consensus of analysts suggests that sales will top the $100 million level before the end of the decade; some think that the environmental seal alone can generate $100 million a year in sales within five years. ●

Ferrofluidics' Alvan Chorney demonstrates use of the environmental seal in a model of a refinery pump.

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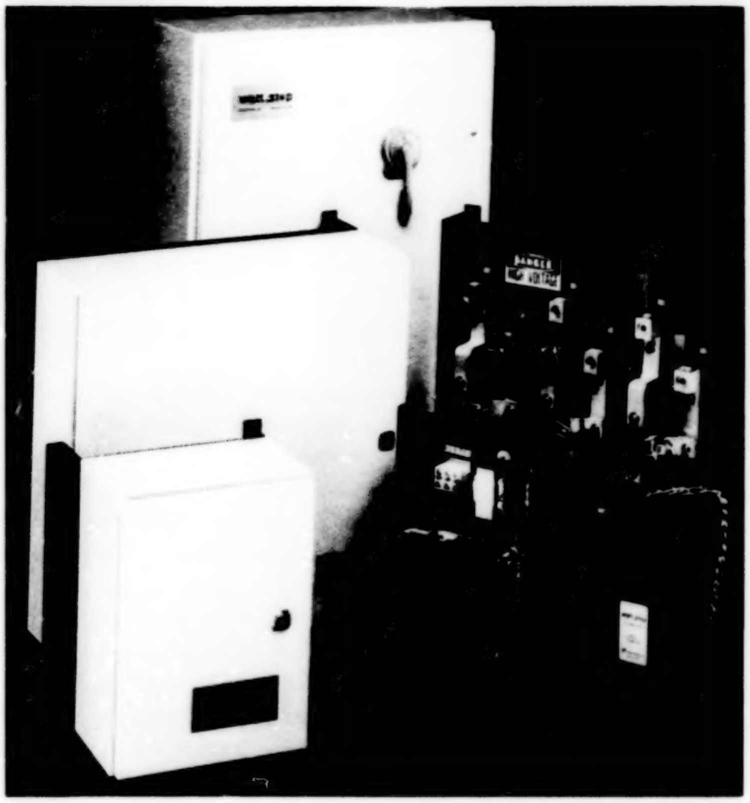
* Ferrofluidic is a registered trademark of Ferrofluidics Corporation.

Smart Starter

A "SMART STARTER" MATCHES A MOTOR'S LOAD AND VOLTAGE FOR MAXIMAL EFFICIENCY

At right are three of the seven-model family of Wattstop™ Reduced Voltage AC Motor Starters manufactured by Firing Circuits Inc., Norwalk, Connecticut. Wattstop solid state starters are designed to provide an effective and economical method of starting standard three phase AC motors. By applying voltage to the motor gradually, they reduce the harmful effects of "slam" starting (mechanical shock and electrical power surges), which in turn cuts maintenance costs and obviates the problem of electrical interference with other loads.



Firing Circuits calls Wattstop the "Smarter Starter." It employs a "smart" microprocessor to monitor the motor's load and set the motor voltage at the level where its operation is most efficient. If the load drops, Wattstop reduces the voltage to lower operating costs; if the load increases, Wattstop immediately brings the voltage up to the proper level. This energy saving feature, standard on all members of the Wattstop family, derives from NASA technology, specifically a device known as the Power Factor Controller (PFC) developed at Marshall Space Flight Center more than a decade ago.

The PFC was invented by Marshall engineer Frank Nola, who came up with a way to curb power wastage in AC induction motors. The wastage is caused by the fact that such motors operate at a fixed voltage, the voltage needed to handle the heaviest loads the motor is designed to carry. Nola's answer was a device — the PFC — that matches voltage with the motor's actual need by continuously sensing shifts between voltage and current; when it senses a light load it cuts the voltage to the minimum needed. The PFC offers potential energy savings ranging from eight to 65 percent, depending on the type of application. It has become one of the most widely used spinoffs of NASA technology, with licensees numbering in the hundreds.

The Wattstop family includes starters ranging from two through 1,500 horsepower and from 208 through 575 volts. They are in service on such equipment as cranes, hoists, conveyors, compressors, fans and pumps, saws, grinders and elevators in such applications as food and beverage processing, materials handling, water and waste treatment, papermaking, plastics, metalworking and woodworking. ●

™ Wattstop is a trademark of Firing Circuits Inc.

Power Switching Device

A NEW CONCEPT IN POWER SWITCHING OFFERS FASTER SWITCHING WITH REDUCED POWER LOSSES

The photo below illustrates the MCT (MOS-Controlled Thyristor), a new type of power switching device for faster and more efficient control and management of power electronics. In this photo is a wafer of 130 MCTs which, if wired in parallel configuration would be able to control about one megawatt of power; a set of switches is shown in the ***adjacent photo***. Manufactured by Harris Semiconductor, Melbourne, Florida, the MCT enables power electronic switching at frequencies of 50 to 100 thousand times a second with much lower power losses than typical of other semiconductor devices.

Harris Semiconductor describes the MCT as "a cost effective solution for high voltage, high-current applications where minimizing conduction losses in the power switch is critical." The MCT offers the power handling capability of a near-ideal thyristor but it is controlled in turn-on/turn-off by a MOS transistor as a gating device. In addition to fewer induction losses and higher switching speed, MCT advantages include electric power savings, lighter weight, smaller space and fewer power losses, which combine to reduce operating costs.

The MCT is typically used in inverters, motor controllers and power controllers. An example of its effectiveness cited by Harris Semiconductor is its application in an electric car inverter evaluated by the Department of Energy and auto industry engineers; prototype MCTs used for power conversion allowed a significant increase in power efficiency in comparison with other thyristors and transistors. Other applications include switching power supplies, AC and DC motor drives, pulse circuits and induction heating.

The MCT resulted from a long development effort that was supported in its early stages by Lewis Research Center. Interested in electroactivation as a replacement for hydraulic devices used in aircraft and space systems, Lewis awarded an initial development contract to General Electric Company. The development was further funded by a consortium of several government agencies, including NASA, and the Electric Power Research Institute. The development effort was conducted by Dr. Vic Temple and his associates at GE. Harris Semiconductor subsequently purchased GE's power semiconductor operation and Temple, along with his department, moved from GE to Harris. The MCT was introduced to the commercial market in 1992. ●

Software Products

A VERSATILE NASA-DEVELOPED PROGRAM FINDS SECONDARY UTILITY IN DAIRY MANAGEMENT, E-MAIL AND ARCHITECTURE

At Cornell University's Department of Animal Science, researcher Dr. Lawrence R. Jones and his colleagues are developing decision support systems to help in management of dairy herds. NASA-developed software is providing an assist.

The dairy industry maintains a nationwide record system — the Dairy Herd Improvement Association — which collects data on dairy herds around the country and processes the information at nine regional centers, one of them at Cornell. Data for groups of herds can be imported into Dr. Jones' system, which is known as MAST.

The goal is to boil the data down to a pool of easily understood information for herd managers. To help them make decisions, MAST draws conclusions from the data and summarizes it graphically. To give the system the ability to make decisions without user interaction, the Jones team uses NASA's CLIPS (C Language Integrated Production System).

Developed by Johnson Space Center, CLIPS is a shell for developing expert systems. It is designed to permit research, development and delivery of artificial intelligence on conventional computers. It is based on an algorithm that enables very efficient pattern matching. A collection of conditions, and the actions to be taken if these conditions are met, is constructed into a rule network. As facts are asserted prior to or during a session, they are matched to the rule network.

In the dairy application, the MAST system with an embedded CLIPS shell analyzes an attribute of milk called "linear score." Linear score is related to udder health and, along with milk production, is measured monthly. The lower the linear score, the better the quality of milk. Using the collected herd data, the program first performs a statistical analysis to determine which parts of the herd are up or down in linear score. These results are passed to CLIPS, which draws conclusions for the user. Through this technique dairy managers are able to identify herd problems more rapidly and the end result is improved animal health and higher milk quality.

CLIPS was supplied to Dr. Jones by the Computer Software Management and Information Center (COSMIC)* located at the University of Georgia. COSMIC is NASA's mechanism for making available to industry government developed computer programs that have secondary applicability.

The versatility and portability of CLIPS have made it a valuable tool for a wide variety of applications. Another example of how CLIPS is contributing to industrial productivity is its use by Clarity Software, Inc., Mountain View, California. With the help of COSMIC-supplied CLIPS, Clarity has developed a "smart" mail program to meet increasing demand for a simple mail handling program occasioned by the snowballing

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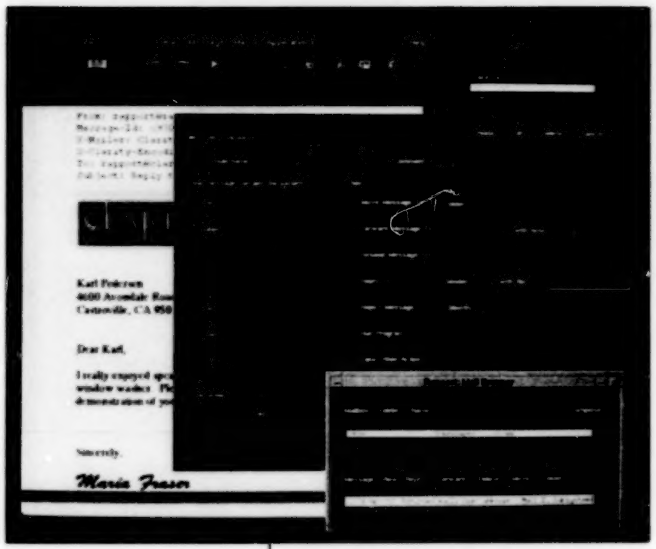

Karl Pedersen

Dear Karl,

Sincerely,

Maria Fraser

growth of E-mail; ***shown above*** is a screen shot illustrating the mail filters in the software product Clarity Rapport.

Clarity's program helps users compose complex rules for managing their E-mail. The user defines rules based on the "header fields" of a mail message — the sender and his title, subject, date and other pertinent data. With a simple graphical interface, the user can then set conditions on the fields, followed by actions to be taken on completion of the conditions. Example: a person going on vacation could set his mail program to filter out junk mail and forward or file other mail depending on its importance.

Clarity saved time and money by using CLIPS rather than developing a comparable tool. Says company engineer Terry Cline, "Without CLIPS we would have had to write our own rule engine because there were not a lot of tools of this type that could be embedded in an application." Use of CLIPS enabled Clarity to push its product to the market faster and gain a competitive edge.

A third example of CLIPS' utility is its use by the CAD (Computer Aided Design) Research Unit at California Polytechnic State University, which is developing software to automate the complicated and costly process of consultation and revision among architects, structural engineers and other specialists involved in home or office building design. The effort is being sponsored by computer companies, among them Accugraph Corporation, El Paso, Texas.

Under the direction of Dr. Jens Pohl, the CAD research team has developed a system called ICADS (Intelligence Computer Aided Design System). ICADS consists of a number of expert systems developed through use of CLIPS.

ICADS is designed to run under Accugraph's MountainTop CAD and Graphic Information Management Software (***below***). MountainTop provides the graphics environment for ICADS. The electronic "experts" monitor the designs of the architect and offer suggestions, comments and information. Some of the experts that can be consulted under ICADS are a structural analyst, lighting expert, cost advisor and acoustical consultant. The experts advise the architect as he is designing, allowing him to avoid mistakes that could cause major revisions. Accugraph is planning to incorporate this form of artificial intelligence into future releases of MountainTop and CLIPS will be used to create the expert systems. ●

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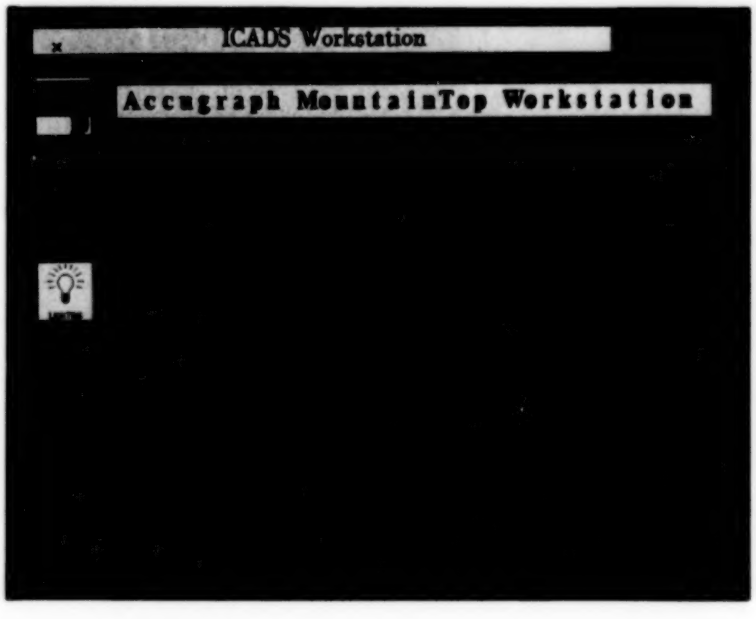
* COSMIC is a registered trademark of the National Aeronautics and Space Administration.



Welding Sensor System

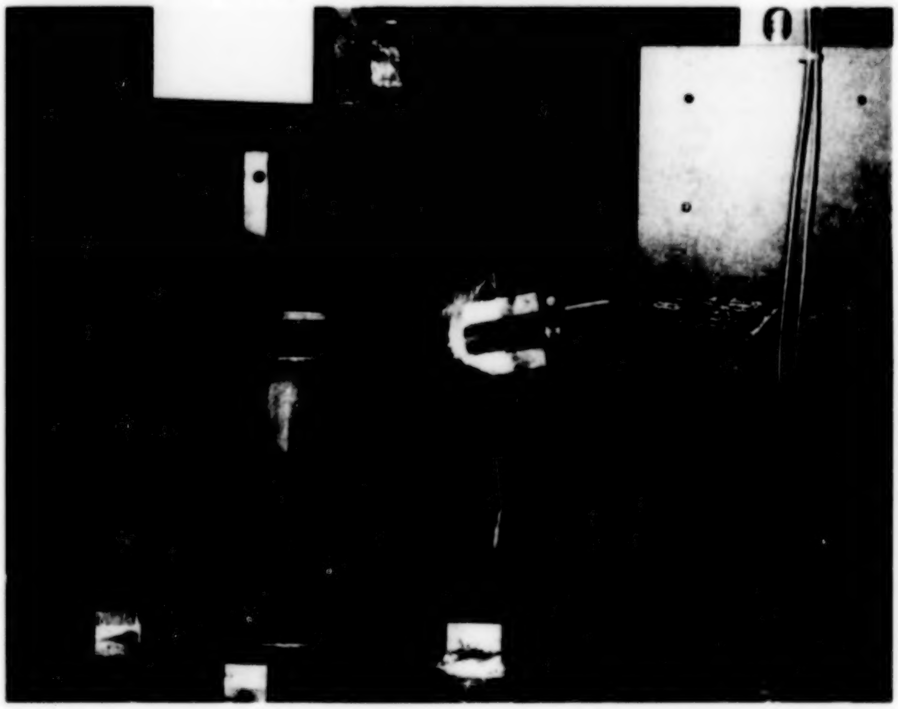
SPACE SHUTTLE TECHNOLOGY SPAWNS A LASER-BASED AUTOMATED WELDER FOR INDUSTRIAL USE

The accompanying photos show a demonstration of a new ARI Weld Sensor System being marketed by Applied Research, Inc. (ARI), Huntsville, Alabama. It is a modified version of a system originally designed at Marshall Space Flight Center (MSFC) for welding components of the huge Space Shuttle External Tank. The modification was accomplished as a cooperative project of MSFC, ARI and Martin Marietta Manned Space Systems, New Orleans, Louisiana, NASA's prime contractor for the External Tank.

Key to the weld technology is a laser sensor that tracks the seam where two pieces of metal are to be joined, measures gaps and minute misfits, and automatically corrects the welding torch distance and height. The system uses a small industrial computer to translate the sensor's information to the weld head; the computer also records and displays extensive weld data for control purposes and statistical process control analysis.

After a series of laboratory tests at MSFC, a proof of concept test was successfully conducted at a manufacturing facility of Copeland Corporation, Hartselle, Alabama. Copeland, a leading manufacturer of compressors for home air conditioning applications, produces some 6,500 air conditioner canisters daily. The necessity for producing a quality, airtight weld at that high volume made the Copeland facility an ideal candidate for operational testing of the system. In late 1991, a run of several hundred canisters was completed.

The automated weld joint tracking system is expected to find wide application in industrial welding processes, especially those that require repetitive operations and a high degree of reliability. The commercial system is being produced by ARI, which pays royalties to co-developer Martin Marietta. The latter company is also a customer; the ARI Weld Sensor System will be part of a new robotically-controlled facility for manufacturing launch vehicle fuel tanks at Martin Marietta's Denver plant. ●

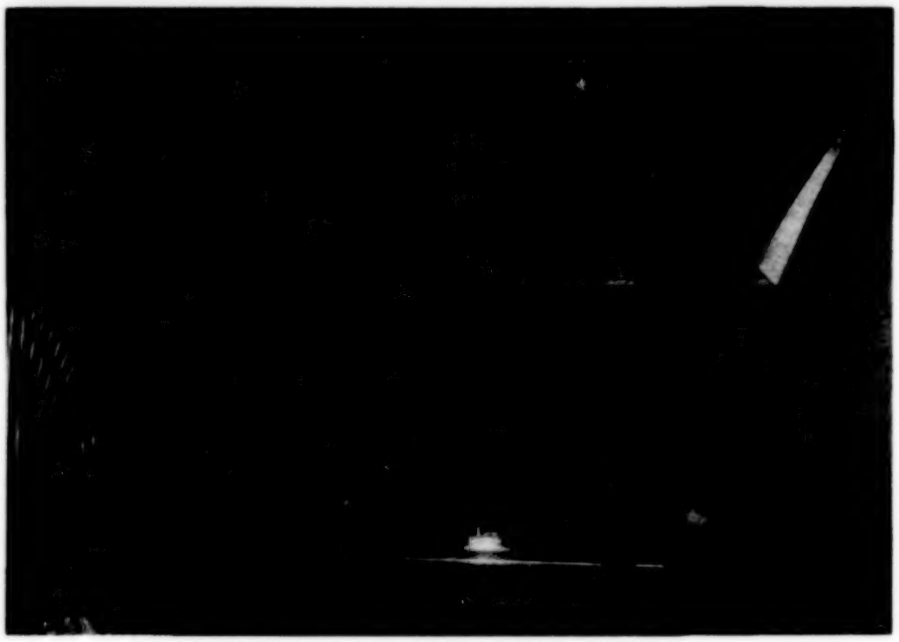


Heat Flow Measurement

AN INNOVATIVE HEAT GAUGE CHECKER OFFERS PORTABILITY AND COST EFFECTIVENESS

In many industrial activities it is necessary to measure heat flow by some type of heat gauge. To assure the validity of the measurements, heat gauges must periodically be certified by instruments designed to provide a heat flux measurement standard, such as the federal government's NIST standard.

Certification can sometimes take the heat gauge away from its needed location for an unacceptably long time, causing delay in measurement work or use of a duplicate gauge. There is need, therefore, for a portable heat measurement checker/calibrator, referenceable to a measurement standard, that can be carried to the heat gauge location for certification, thus reducing out of service time for the gauge and eliminating the need for a duplicate.



The Center for Space Transportation and Applied Research, located at the University of Tennessee Space Institute, Tullahoma, Tennessee, and REMTECH, Inc., Huntsville, Alabama, have responded to the need. CSTAR, one of NASA's Centers for the Commercial Development of Space, developed the Q-CHEC portable heat flux checker/calibrator pictured ***below***, where co-developers Carl Kidd (striped shirt) and R. K. Matthews are calibrating the instrument's handheld radiant heat source to NIST standards. REMTECH, CSTAR's industrial partner, is marketing the unit.

Q-CHEC can be used in two primary modes. It can provide an "end-to-end" check of the complete heat gauge instrumentation measurement system by applying the known radiant heat flux — provided by Q-CHEC — to the heat gauge itself while the measurement system is recording the heat gauge output. This use verifies the recording system as well as the heat gauge.

The unit can also be used as a standalone heat flux gauge checker/calibrator in which the heat gauge is connected to the Q-CHEC directly, so that its output may be recorded separately. The gauge is irradiated by the known heat flux provided by Q-CHEC as in the end-to-end mode, but in this case output is recorded directly by Q-CHEC. These values are either compared with an existing calibration or used with several additional test points to form a new gauge calibration.

Q-CHEC offers on-site capability to detect and eliminate measurement errors caused by deviations of gauge scale factors, wrong recorder gains, wrong channel assignments or wrong hook-up polarities. It also offers money savings, because these fairly common errors become expensive when the measurements have to be repeated. ●

Process Analyzer

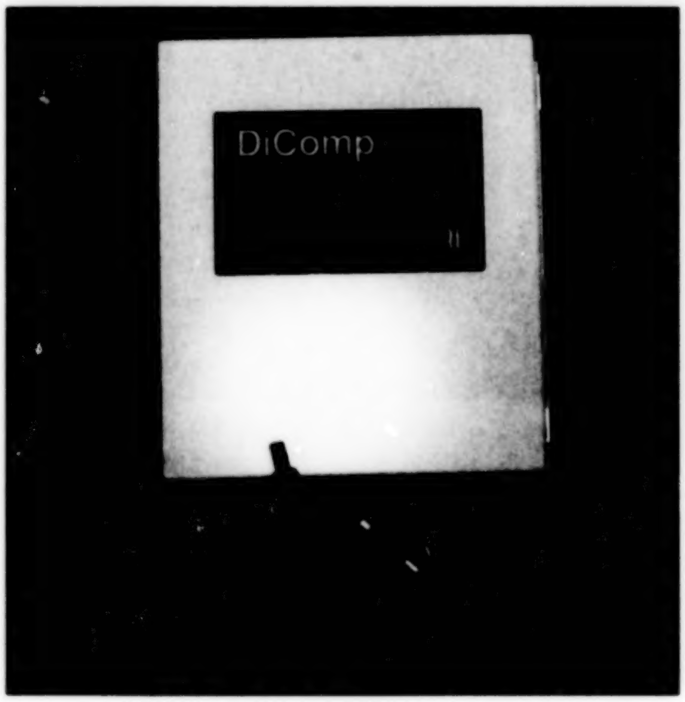
SPACE LIFE SUPPORT RESEARCH YIELDS A SPINOFF COMMERCIAL PROCESS ANALYZER

In 1990, Axiomatics Corporation, Woburn, Massachusetts was awarded a NASA Small Business Innovation Research contract for development of a sensing and measurement device to be used in the Controlled Ecological Life Support System (CELSS) at Kennedy Space Center. Under that contract, Axiomatics developed the DiComp™ Shunting Dielectric Sensor to determine the nutrient level and analyze plant nutrient solutions in the CELSS, an experimental facility investigating closed-cycle plant growth and food processing for long duration manned missions.

Axiomatics then further developed the DiComp system for similar measurement needs in commercial process analysis. The resulting product is the DiComp Process Analyzer, introduced in October 1992.

The analyzer is based on the Shunting Dielectric Sensor developed for NASA, described by Axiomatics as a "breakthrough" device. The innovation was accomplished by incorporating a shunt electrode into a conventional field sensor. This makes the DiComp sensor especially sensitive to changes in the dielectric property changes in materials, at measurement frequencies much lower than conventional sensors. It gives the analyzer exceptional capabilities for predicting the composition of liquid streams or reactions.

The DiComp Process Analyzer measures concentrations and solids content up to 100 percent in a wide range of applications, among them agricultural products, chemical and petrochemicals, food and beverages, polymers and textiles for both process-oriented and analytical customers. The DiComp sensor features easy installation and low maintenance. DiComp is designed to be easily calibrated on-line, so process streams can be calibrated in place. DiComp software automates data collection and analysis. ●



™ DiComp is a trademark of Axiomatics Corporation.

Laser Analyzer

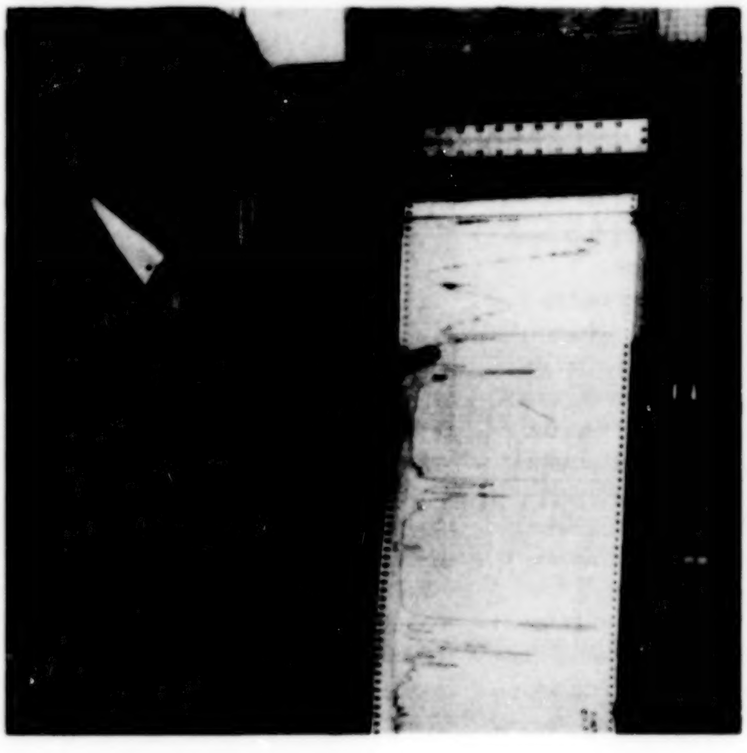
CRYSTAL RESEARCH PRODUCED A PROCESS FOR IMPROVING THE EFFICIENCY OF LASER RODS

Scientific Materials Corporation (SM), Bozeman, Montana is a small company with a big reputation in the field of producing laser crystals. Founded in 1982 by Ralph L. Hutcheson, SM's president, a crystal pioneer with almost 40 years experience, the company worked on two NASA Small Business Innovation Research (SBIR) contracts and generated two separate commercial spinoffs, one of them a new company.

Under a Langley Research Center SBIR contract, SM developed a SciMax™ line of improved Nd:YAG crystals for laser and electro-optic applications (Nd:YAG is technical shorthand for the materials involved — neodymium, the dopant, and yttrium aluminum garnet, one of the primary materials used in crystal growing). SM's research provided a process for producing uniform laser rods in which the amount of water trapped in the crystal during growth is reduced, thereby improving efficiency, and the properties that affect optical quality are also improved for a further gain in crystal efficiency. SM is producing the crystals for such applications as fiber optics, telecommunications, welding, drilling, eye surgery and medical instrumentation.

SM's spinoff company is Montana Analytical Services, which provides a number of special services and supplies for laser engineers and crystal growers. Among those services, SciMax conducts analysis of laser rods for dopant ion concentrations; ***below***, analytical chemist Martin K. Schwan is performing an analysis of a rare Earth doped YAG crystal. The techniques used to analyze laser rods were developed under another SBIR contract with Langley.

Norman Barnes, Langley's technical director for the SM work, termed the development of an analytical service for accurately measuring laser dopant levels a significant advance. "While solid state lasers have been around for 30 years," he wrote, "analysis of the dopant levels has been lacking. Chemical analyses performed by different companies on similar samples typically yield differences of a factor of two." Dopant level analysis is important to the laser system designer because it allows him to model the laser's performance, and it is important to the end user because it allows determination of what went wrong when the laser fails to perform as expected. ●

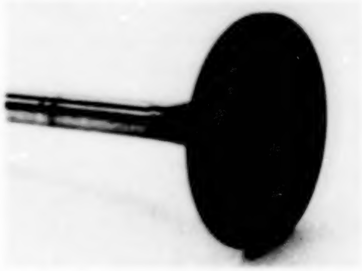


™ SciMax is a trademark of Scientific Materials Corporation.

Thermal Barrier Coatings

AN AEROSPACE ENGINE COMPONENT COATING TECHNOLOGY IS EXTENDED TO NON-AEROSPACE USE

The concept of thermal barrier coating, or TBC, involves placing a thermal insulating layer of material between a metallic engine component and the hot gas heat source to reduce heat transfer to the component. Such coatings, applied by plasma spray processing in thin films typically measuring less than a millimeter, have been used for years to coat metal components of gas turbine and rocket engines for aircraft and spacecraft. Lewis Research Center is a world leader in developing TBC technology.



The successful employment of TBCs in aerospace applications has sparked interest in applying them to non-aerospace turbines and diesel engines. One company that has conducted extensive research in this area is Caterpillar Inc., Peoria, Illinois, a leading manufacturer of earthmoving equipment and heavy duty diesel engines. Caterpillar has been actively pursuing application of ceramic coatings to high temperature components of diesel engines, aided by technical assistance from Lewis Research Center and contractual support from the Department of Energy.

The cooperative effort has resulted in use of ceramic thermal barrier coatings on Caterpillar Series 3600 production engines. These large engines, ranging from 1700 to 6700 horsepower, are used in stationary electric power generation and marine applications. Cat 3600 engines can be configured for optimized operation on distillate fuels or for running on the heaviest fuel available.

Heavy fuels contain high amounts of sulphur and vanadium that, at high combustion temperatures, form corrosive compounds on exhaust valves. With high vanadium fuels, the life of an engine valve can be reduced to as little as 50 hours without design measures to minimize the temperature of the exhaust valve. Caterpillar's answer is use of watercooled valve inserts, a corrosion resistant Nimonic 80A material in the exhaust valves, and a unique ceramic coating on the exhaust valve head (***left above***) to control temperatures, extend valve life and reduce operating cost.

Application of the ceramic coatings is accomplished by a process developed by the Caterpillar Technical Center in Peoria. High quality coatings are ensured by a fully automated plasma spray cell (***below***) that includes computerized plasma spray equipment capable of monitoring and controlling all spray variables, a six-axis robot for manipulating the spray gun, and a laser gauge for monitoring coating thickness as it is built up.

Caterpillar and NASA are continuing their collaboration, extending thermal barrier coating technology to other applications, such as heavy duty truck engines. For this application, they are testing TTBCs (thick thermal barrier coatings), which are as thick as four millimeters. TTBCs applied to pistons and engine heads insulate the engine, raise the combustion temperature and increase the engine's fuel efficiency. ●

Piping Connector

A SPECIAL TYPE OF CONNECTOR SOLVES A PROBLEM OF LEAKAGE IN HIGH PRESSURE PIPING

Reflange* Inc., Houston, Texas is a leading company in the field of high pressure piping connector technology. Its metal seal piping connectors are widely used in the hydrocarbon processing, chemical, power, aerospace and other industries, in processes where pressures reach 30,000 pounds per square inch and temperatures top 1650 degrees Fahrenheit.

One of Reflange's latest products, the T-Con* connector, is a commercial spinoff of a connector specially developed for the demanding requirements of a complex of high pressure piping at Stennis Space Center's (SSC) Component Test Facility (CTF), where NASA tests rocket engine components.

In the design phase of the CTF's development, it was originally planned to use conventional clamped connectors on the CTF piping lines that carry rocket propellants and other fluids/gases. But Marshall Space Flight Center commented that its experience with similar connectors was that they were not suitable for use on lines that carry high pressure cryogenic (extremely low temperature) fuels; similar connectors leaked when the propellant lines were chilled to pretest temperature of 400 degrees below zero Fahrenheit.

Haynes Haselmaier, an engineer with Johnson Control World Services, the SSC facilities contractor, contacted several manufacturers of clamped connectors, advised them of concerns about leakage and sought solutions. One — Reflange, Inc. — expressed interest in customizing an existing design to include a secondary seal more tolerant of severe thermal gradients. After tests of a prototype at SSC, and further refinement of the secondary seal arrangement, Reflange produced a connector that solved the problem. NASA officials elected to use the new T-Con connector (*left*) in all CTF locations where severe thermal shock was anticipated.

The commercial T-Con, with the secondary face seal for thermal shock applications in industrial service, includes an annular port that permits testing, monitoring or collecting any emissions that might escape the primary seal during severe thermal transition. ***Below***, designer Kathy Hammett prepares a design for a custom application; in the foreground are the two different sized seals employed in the T-Con. ●

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* Reflange and T-Con are registered trademarks of Reflange Inc.

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Hollow Retroreflectors

AN ADVANCEMENT OF A NASA SPACE SYSTEM OFFERS NEW EFFICIENCY IN OPTICAL ALIGNMENT AND BEAM POSITIONING

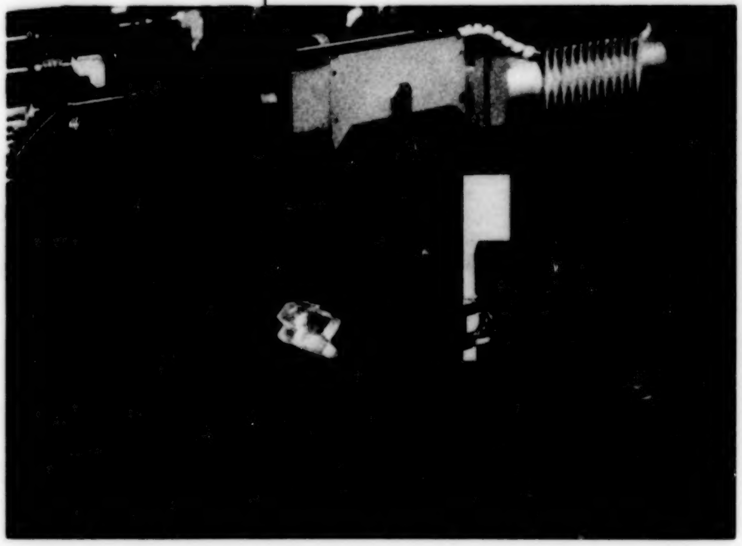
PLX, Inc., Deer Park, New York (formerly Precision Lapping & Optical Company) manufactures high technology optical equipment for aerospace and defense companies, government organizations, research laboratories and commercial instrument companies. The company is a leading producer of hollow retroreflectors, mirror-like instruments that reflect light and other radiations back to the source.

PLX's experience in that product line dates to the mid-1970s, when the company developed a hollow retroflector for NASA's use on the Apollo-Soyuz mission. As Apollo and the Soviet Soyuz orbited Earth a fixed distance apart, Apollo sent a beam of ultraviolet radiation to the retroreflector array on Soyuz, which bounced it back to an instrument in Apollo that measured the amount of radiation absorbed; that provided clues to the densities and concentrations of gases in the atmosphere. The Apollo-Soyuz work made PLX a pioneer in retroreflector development and over the years the company has developed a wide variety of retroreflector systems for applications involving the entire optical spectrum.

PLX has significantly expanded the technology with the introduction of a new Lateral Transfer Hollow Retroreflector (LTHR), shown in the foreground of the photo ***below left***, which accurately shifts a beam laterally while changing its direction 180 degrees — it uses a system of mirrors to return an exiting beam parallel to but laterally separated from the incoming beam as illustrated ***below right***. The device maintains precise separation of the two beams regardless of its own orientation and at any wavelength.

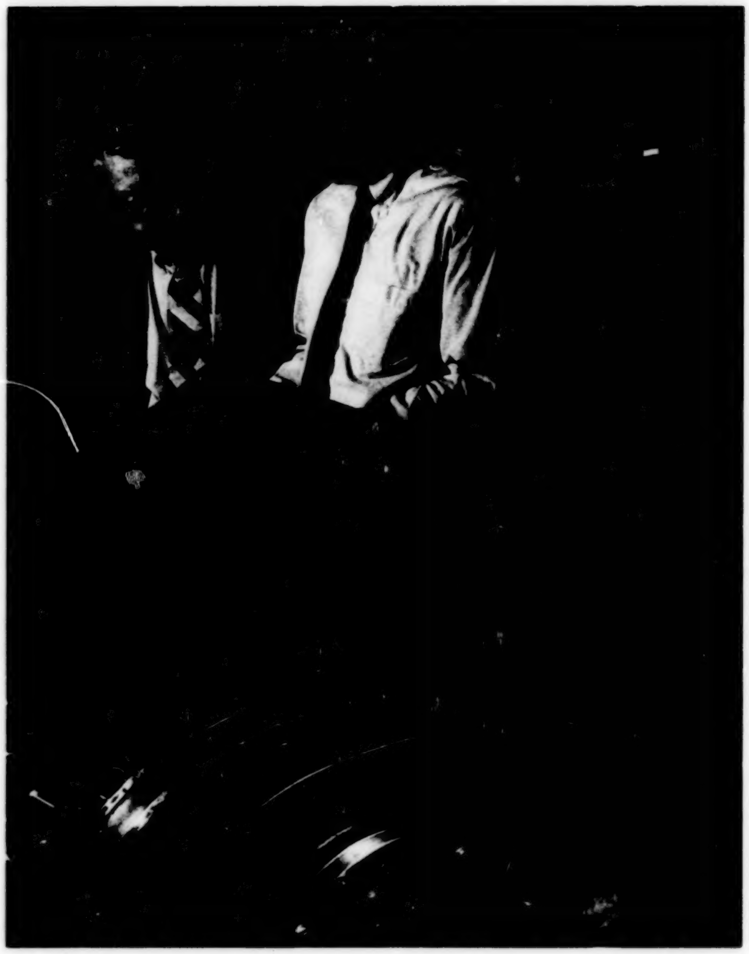
The first commercially available offset hollow retroflector, the LTHR can be used either as an instrument or as a component of an optical system. In measurement of laboratory equipment alignments, it offers a new, efficient means of beam positioning; much of the elaborate, costly optical setup normally needed can be eliminated, and the LTHR needs no monitoring or readjustment. In non-laboratory applications and as an instrument component, the LTHR is useful in general boresighting and alignment, connecting laser resonators, telescope mirror alignment, and alignment of laser designator systems for defense applications.

NASA, which provided the initial impetus for PLX's hollow retroreflector developments, is one of the company's LTHR customers. NASA has taken delivery of several of the devices for use in optical alignment and environmental research; one unit is a component of the Advanced X-ray Astrophysics Facility, an orbiting observatory being developed for service in the late 1990s. ●



Engine Lubricant

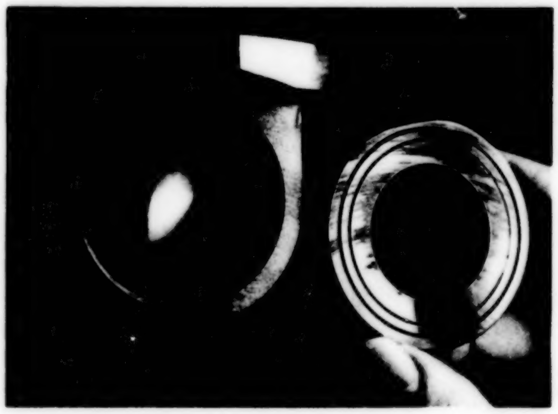
NASA COATING TECHNOLOGY IS INCORPORATED IN A NOVEL AUTOMOTIVE ENGINE



Murray United Development Corporation (MUDCO), Landing, New Jersey is a research and development firm founded by well-known inventor Jerome L. Murray, holder of more than 50 patents, among them the rotating TV antenna, electric carving knife, high speed dental drill and peristaltic heart pump. MUDCO's principal current project is a novel Rotorcam engine designed principally for automobile use but also applicable to light aircraft, boats, stationary engines or lawn mowers. ***Above***, Murray (striped tie) and chief engineer Al Richey look over the specifications for a test run of the engine, which is shown in the foreground.

The Rotorcam has no crankshaft, flywheel, distributor, or water pump and it can run on virtually any kind of fuel. It is a rotary engine, only 10 inches long, with four cylinders radiating outward from a central axle like spokes on a wheel; in operation, the cylinders rotate past stationary fuel and exhaust ports and a single, centrally located spark plug. MUDCO officials say that a production version of the engine will be lighter, more compact and cheaper to manufacture than current auto engine types and will feature cleaner exhaust emissions. Prototype engines have been extensively tested and MUDCO hopes to effect a licensing arrangement with a manufacturer in the near future.

NASA technology is incorporated in the Rotorcam engine in the form of a valve coating. MUDCO chief engineer Richey was aware of Lewis Research Center's development of a family of materials that provide engine lubrication over a wide temperature range. MUDCO selected the plasma-sprayed PS 212 as a coating for the Rotorcam's valves to eliminate the need for a liquid lubricant. PS 212 contains 70 percent chromium carbide, 15 percent silver and 15 percent barium fluoride/calcium fluoride; the carbide acts as a wear resistant matrix and the silver and fluorides serve as low and high temperature lubricants, respectively. In 1992, MUDCO tested the Rotorcam with PS 212 coated valves and found the material to be the answer to their requirement. ***Below*** is a PS212-coated port seal of the Rotocam engine. ●



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TECHNOLOGY TRANSFER

A description of the mechanisms employed to encourage and facilitate practical application of new technologies developed in the course of NASA activities.

PUTTING TECHNOLOGY TO WORK

Because they are challenging and technologically demanding, NASA programs generate a great wealth of advanced technology. This bank of technology is a national asset that can be reused to develop new products and processes to the benefit of the U.S. economy in new companies, new jobs and resulting contributions to the Gross National Product.

Such "spinoff" applications do not happen automatically. It takes a well-organized effort to put the technology to work in new ways and to reap thereby a dividend on the national investment in aerospace research.

NASA accomplishes that end by means of its Technology Transfer Program, which employs a variety of mechanisms to stimulate the transfer of aerospace technology to other sectors of the economy. The program is managed by the Technology Transfer Division of NASA's Office of Advanced Concepts and Technology. Headquartered in Washington, D.C., the division coordinates the activities of technology transfer offices located throughout the United States.

A NATIONWIDE TECHNOLOGY TRANSFER NETWORK SEEKS TO BROADEN AND ACCELERATE SECONDARY APPLICATION OF NASA TECHNOLOGY

One of the program's most important mechanisms is the Technology Utilization Officer, or TUO, a technology transfer expert located at each of NASA's nine field centers. He serves as a regional manager for NASA's Technology Transfer Program.

Representative of this group is Ismail Akbay, Director of the Technology Utilization Office at Marshall Space Flight Center (MSFC). His principal assistants are Nell Massey, manager for contractor compliance; Dr. Kenneth Fernandez, outreach manager; and John Richardson, manager for new technology reporting.

Akbay's basic responsibility — and that of the other NASA TUOs — is to stay abreast of research and engineering activities at his center that have potential for generating transferrable technology. He assures that the center's professional people identify, document and report new technologies developed in the center's laboratories and, together with other center personnel, he monitors the center's R&D contracts to see that NASA contractors similarly document and report new technology, as is required by law. This technology, whether developed in-house or by contractors, becomes part of the NASA technology bank available for transfer.

The TUO also serves as a point of liaison among industry representatives and personnel at his center, and between center personnel involved in applications engineering projects, efforts to solve public sector problems through the application of pertinent aerospace technology. On such projects, the TUO prepares and coordinates applications engineering proposals for joint funding and participation by federal agencies and industrial firms.

NASA conducts, independently or in cooperation with other organizations, conferences, seminars and workshops designed to encourage broader

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Ismail Akbay (right), Director of Marshall Space Flight Center's Technology Utilization Office, inspects a mockup of a space station laboratory module at Marshall. With him are his principal assistants, Nell Massey, manager for contractor compliance, and Dr. Kenneth Fernandez, outreach manager. Technology Utilization Officers at each of NASA's nine field centers play important parts in NASA's Technology Transfer Program.

private sector participation in the technology transfer process and to make private companies aware of the NASA technologies that hold promise for commercialization. The TUO plays a prominent part in this aspect of the program. He arranges and coordinates his center's activities relative to the meetings and when — as frequently happens —industry participants seek to follow up with visits to the center, he serves as the contact point.

MSFC conducts an extensive outreach program under the aegis of the Technology Utilization Office. The center has Memoranda of Understanding with the state governments of Alabama, Mississippi, Tennessee, Louisiana, Georgia and West Virginia for the promotion of technology transfer. Akbay and his staff maintain lines of communication with state economic development officials and Chambers of Commerce and have reached many in the industrial community with the message that technology transfer offers significant benefits to government and industry alike.

In three states, MSFC and state officials have teamed to conduct systematic county-by-county surveys of industrial plants seeking opportunities to solve industrial problems by applying NASA technology. This ongoing effort has resulted in a flood of problem statements and technical inquiries from industry. To handle the rush of new business, MSFC formed a Technology Action Board (TAB) within the TU Office and established a database of incoming problem statements and technical requests. Over a three year period, the TAB has handled more than 800 problem statements requiring varying levels of assistance from MSFC. A number of major MSFC-industry cooperative projects has resulted.

In addition to the TUOs, other mechanisms employed in the Technology Transfer Program include a network of technical assistance centers that provide, to government and industry clients, access to a great national data bank; applications engineering projects, in which NASA collaborates with public sector or industrial organizations to develop innovative solutions to major problems through redesign or reengineering of NASA technology; a software center that offers computer programs applicable to secondary use; and a publication that informs potential users of technology available for transfer. These mechanisms are detailed in the following pages. ●

Technology Transfer Network

To promote technology transfer, NASA operates a number of user assistance centers whose job is to provide information retrieval services and technical help to industrial and government clients.

Intended to meet the technological needs of American industry and boost U.S. competitiveness, the National Technology Transfer Network is composed of a National Technology Transfer Center (see page 136) and six regional Technology Transfer Centers (RTTCs). The RTTCs are geographically located to provide an equal distribution of services throughout the country. The regional deployment of the centers, and their alignment with the Federal Laboratory Consortium, allows the RTTCs to work closely with federal, state and local programs in serving the technology-related needs of business and industry.

The RTTCs provide value-added services to meet the needs of clients, including:

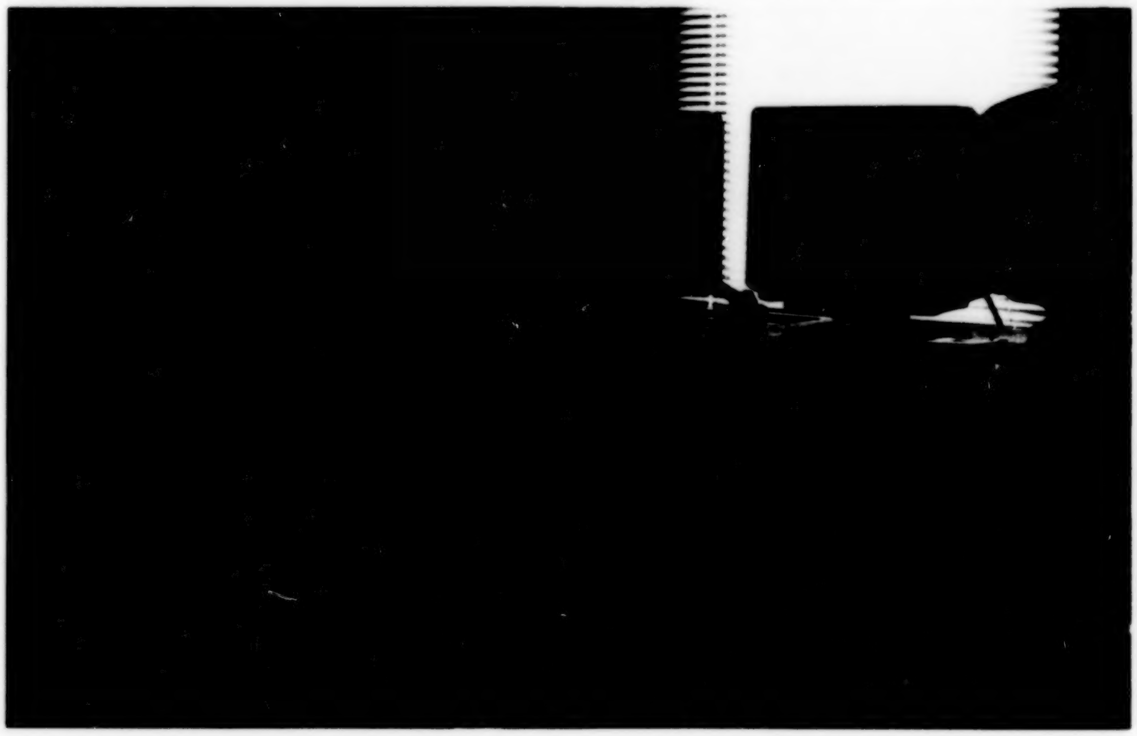
- Information services: computerized searches of federal technology databases and other technology sources.
- Technical services: assessment of technology requirements, analysis of technology applications, and engineering reports.
- Commercialization services: technology brokering, business analyses and venture capital sourcing.

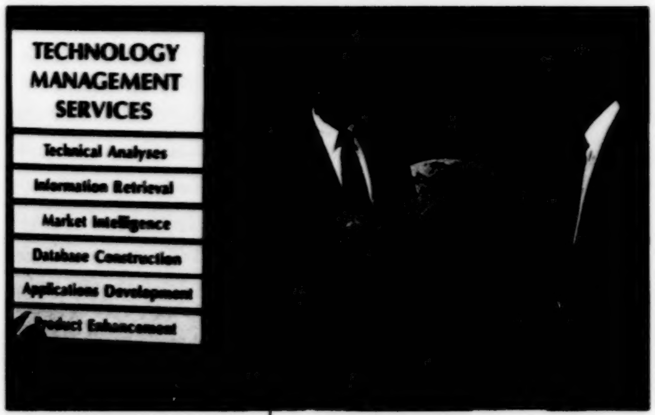
Other elements of the National Technology Transfer Network include:

- Federal agency technology transfer programs and activities.
- State and local agencies and their programs, such as technology centers and business/technical assistance services.
- Business and industry consortia, associations and communities.

A typical RTTC is the Mid-Atlantic Technology Applications Center (MTAC), located at the University of Pittsburgh (Pennsylvania). Its network of Associates and its field staff serve the Mid-Atlantic region that includes Pennsylvania, Delaware, the District of Columbia, Maryland, Virginia and West Virginia. The Associates are technology transfer outposts, located at host institutions in the region, who provide local access to the same type of information as is available from MTAC.

MTAC provides a wide range of technology management services, including information retrieval, technical analyses and assessments, market intelligence, product enhancement and applications development. MTAC conducts searches in a





wide variety of commercially available government and proprietary databases to provide information on state-of-the-art developments in a particular field, individuals and organizations conducting relevant R&D, patents and licenses, and technologies that can be redeployed or reengineered to meet a client's needs.

After searching the databases, MTAC investigates non-computerized sources of information such as traditional print materials. Experts from NASA field centers, federal laboratories, universities and industrial organizations are contacted to locate additional information. For example, MTAC has access to departments within the University of Pittsburgh for help in such areas as chemistry, biotechnology, engineering and materials sciences. Additionally, it can call upon experts from the university's Applied Research Family, including the Center for Hazardous Materials Research, National Environmental Technology Corporation, and Concurrent Technologies Corporation.

The MTAC Teachers Resource Center supports NASA's educational objectives by providing teachers immediate access to information generated by NASA programs. The center makes available scientific and technical materials related to research and technological developments in the areas of life sciences, physical science, astronomy, energy, Earth resources, geology, mathematics, aeronautics and space flight.

To enhance private sector access to the technological information housed in the nation's federal laboratories, MTAC has developed a tool that allows businesses to tap into the network of federal R&D resources. The *Federal Laboratories Database* is a user-friendly desktop computer program containing information on almost 2,000 federally-funded R&D laboratories and facilities.

At ***far lower left***, MTAC executive director Lani Hummel (center) is pictured in a meeting with deputy director Jan Miller and project manager Ronald Edwards. The photo ***at left*** exemplifies one of the most effective ways in which MTAC seeks out contacts in the business community: through booth contact at various trade shows. ***Below***, an MTAC staffer at the Teacher Resource Center helps a teacher search for materials to enliven lesson plans.

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Technology Transfer Network

(CONTINUED)

The hub of the National Technology Transfer Network is the National Technology Transfer Center (NTTC), located at Wheeling Jesuit College, Wheeling, West Virginia. Now in the early phase of a five-year development program, the NTTC is intended to serve as the national clearinghouse for federal technology transfer, linking U.S. firms with federal agencies and laboratories, the RTTCs, and state and local agencies.

One of the center's first steps in the interest of enhanced U.S. competitiveness was establishment of a "gateway service," a toll-free telephone access to a full federal technology database and indexing system. By calling a 1-800 number, U.S. companies can access the federal laboratory system in search of technologies and research data that can assist them in developing their businesses. Users do not communicate with a machine, but with a highly trained professional who helps transfer technology from the federal shelf to the shop floor; ***at right***, an NTTC technology access agent is taking a call from an industrial client.

The NTTC also provides training and educational services to government and industry to develop the skills essential to effective technology transfer. Additionally, the center conducts outreach and promotional activities to improve private sector awareness of technology transfer opportunities.

One such activity is NTTC's national electronic bulletin service for both the public and private sectors of the U.S. technology transfer community. The free service includes notices of upcoming technology transfer related meetings, announcements of new technologies, problem query/answer communications, success stories and postings of opportunities.

The service additionally includes an electronic mail function, search access to federal laboratory data and a telephone directory of technology transfer individuals, resources,

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agencies and associated entities.

Support for all the elements of the National Technology Transfer Network is provided by the Technology Transfer Office at the Center for AeroSpace Information (CASI). This office executes a wide variety of tasks, among them maintenance of the subscription list for *NASA Tech Briefs*, the principal tool for advising potential users of technologies available for transfer; maintenance and mailout of Technical Support Packages, which provide details of new technologies, involving a reproduction effort of more than 1.5 million pages annually; and responding to requests for information, an activity that entails processing of some 60,000 letters and other inquiries and mailout of more than 300,000 documents a year. The office additionally serves as a "help desk," channeling information seekers to the proper agency or organization when the information is not available at CASI.

Pictured on the ***opposite page, bottom***, are Walter M. Heiland (standing), manager of the CASI Technology Transfer Office and, from left to right, staffers Jane Lynn-Jones, Lenora Parris and Sharleen Angyelof; ***above*** are data entry operators Judy Hebert, Mary Crum and Kelen White; ***at left***, Bobbi Ebberts (standing) and LaDonna Jenkins are processing requests for Technical Support Packages.

The CASI Technology Transfer Office is also responsible for research, analysis and other work associated with this annual *Spinoff* volume; for distribution of technology transfer publications; for retrieval of technical information and referral of highly detailed technical requests to appropriate offices; for developing reference and bibliographical data; and for public relations activities connected with media, industry and trade show interest in technology transfer matters. ●

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Technology Applications

Applications engineering projects are efforts in which NASA seeks to solve significant public sector or industrial problems through redesign or reengineering of existing technology. They originate in various ways. Some stem from requests for assistance from other government agencies; others are generated by NASA technologists who perceive possible solutions to problems by adapting NASA technology to the need. NASA also employs an applications team composed of scientists and engineers representing different areas of expertise, who identify problems, submit them to NASA centers for review, then assist the centers in adapting solutions.

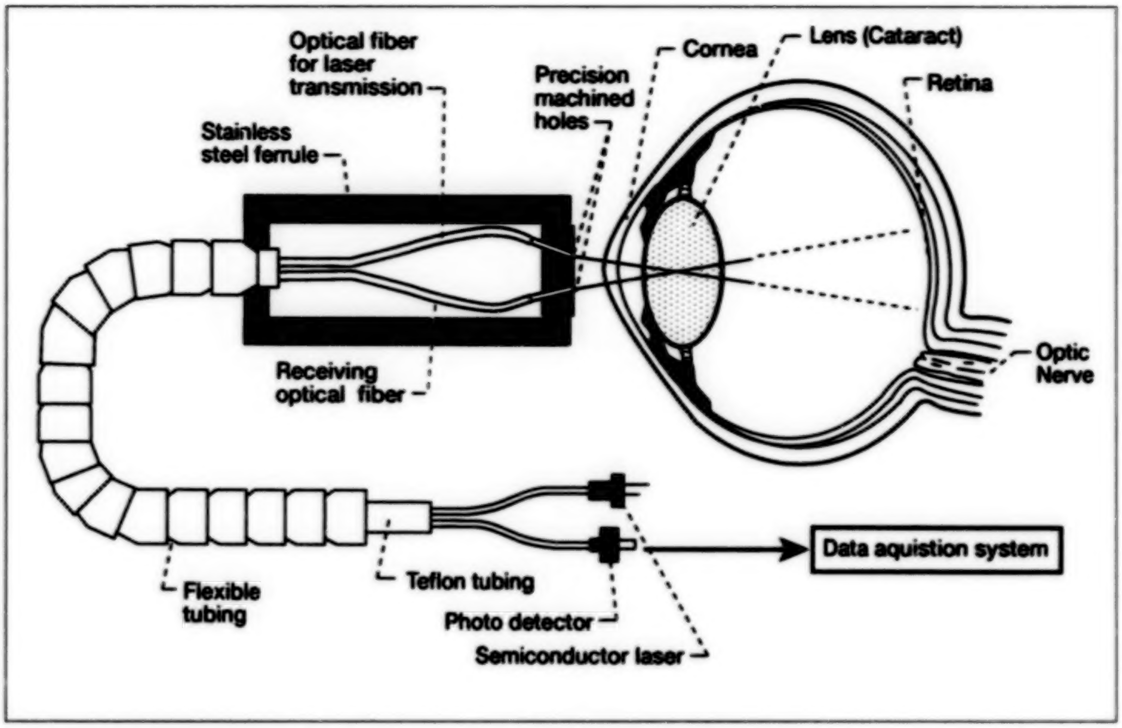
An example of an ongoing applications engineering project involves use of a compact fiber optical probe, originally developed by Lewis Research Center for on-orbit science experiments, to detect the onset of cataracts. The probe is a spin-off of an advanced technology development program in laser light scattering that has reduced a small roomful of electronics, detectors, lasers and associated optics to a package the size of a briefcase.

The probe itself is pocket-size; it is pictured ***below*** in the hand of Dr. Rafat R. Ansari as he conducts an eye examination. Dr. Ansari is holding the instrument for illustrative purposes; actually it is inside the ophthalmoscope he is using. Dr. Ansari, a project scientist at Lewis Research Center and a research professor at Case Western Reserve University, developed the probe jointly with Dr. Harbans Dhadwal of State University of New York at Stonybrook.

In the medical application of the technology, the probe is intended to detect cataracts while they are still in the early formative stage. The instrument detects the presence of protein crystals suspended in the fluid inside the eye's lens. These crystals are suspected of forming over time into a cloudy mass that becomes a cataract.

In use, an optical fiber transmits a low powered laser beam into the eye (the beam is so weak there is no risk of eye damage). Light scattered within the eye is reflected back to the instrument, picked up by a second optical fiber and routed to a detector. The detector's signal is then sent to a laptop computer, which interprets the information contained in the light scattered by the eye lens.

The interpretation is an analysis of the size distribution of protein crystals in the eye lens (a cataract is a group of proteins). The cataract, which is caused by a change in the



biochemical composition of the lens, leads to blurred and double vision, sensitivity to light and glare, a less vivid perception of color, and frequent eyeglass prescription changes. At present the only treatment for cataract is surgical removal of the clouded eye lens and replacing it with an artificial lens. The significance of the Lewis Research Center development is that the probe provides a means of detecting cataracts early enough that surgical removal of the lens may not be necessary. The capability for early detection and monitoring the progression of the cataract's development offers the possibility that treatment by diet and medicine may be possible; for example, the probe's findings could lead to develop drugs that could neutralize a forming cataract.

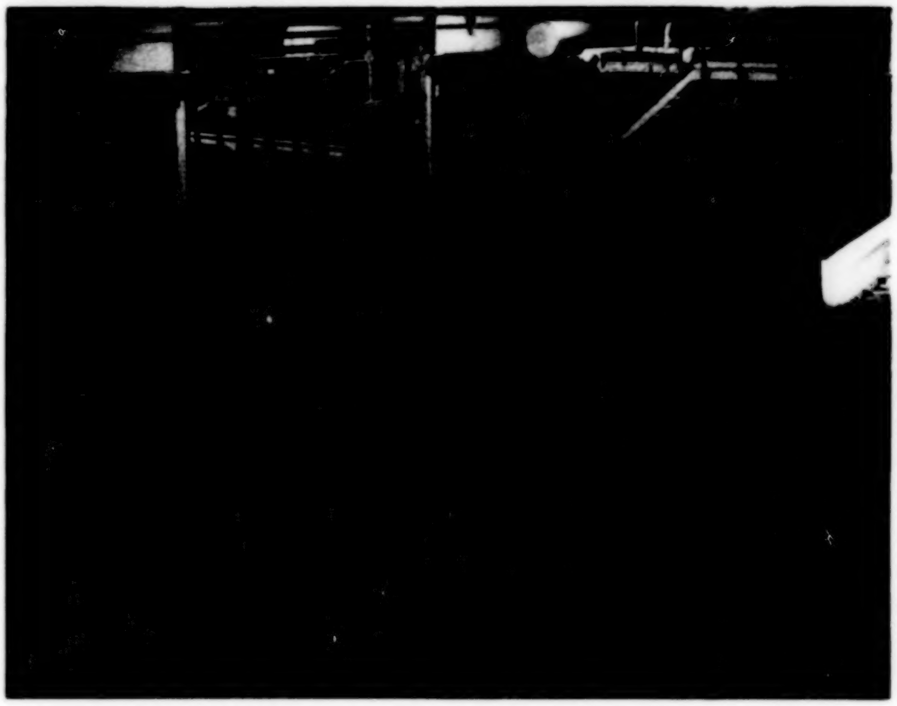
Lewis researchers also believe that the technology may have wide industrial application because the fiber optic probes can measure the sizes of very small particles, down to a few nanometers (billionths of an inch) suspended in solutions ranging from dilute solutions to highly concentrated solutions that would not allow a conventional light scattering instrument to function. ●

Software Center

In the course of its varied activities, NASA makes extensive use of computer programs, as do other technology generating agencies of the government. To meet their software requirements, these agencies have of necessity developed many types of new computer programs.

These programs constitute a valuable resource available for reuse. Much of this software is directly applicable to secondary use with little or no modification; most of it can be adapted to special purposes at a cost far less than that of developing a new program.

Therefore, American businesses can save time and money by taking advantage of a special NASA service that offers software capable of being adapted to new uses. NASA's mechanism for making the software available to business and other clients is the Computer Software Management and Information Center (COSMIC)*.



Located at the University of Georgia, COSMIC gets a continual flow of government developed software and identifies those programs that can be adapted to secondary usage. The center's library contains more than 1,200 programs for such purposes as structural analysis, artificial intelligence, computational fluid dynamics, thermal analysis, image processing, project management and a great variety of other functions. COSMIC customers can purchase a program for a fraction of the original cost and get a return many times the investment, even when the cost of adapting a program to a new use is included.

An example of how this service aids industry is the use of COSMIC-supplied software to Salem Automation, Pittsburgh, Pennsylvania for use in a company research effort seeking methods to increase energy efficiency in reheat furnaces. The reheat furnace (***below***) is an energy intensive stage in steel processing, employed to raise the temperature of steel slabs, blooms or billets to the point where they can be formed by rolling.

Along with other company software, Salem Automation used a COSMIC program to evaluate technology for increasing productivity and reducing energy usage in the reheat process. The COSMIC program — the General Thermal Analysis Program — solves steady state and transient thermal problems using desktop computers. The program enabled simulation of how slabs in a proposed furnace design will heat during operation, allowing changes in the design based on computer predictions before the furnace was actually built. ●

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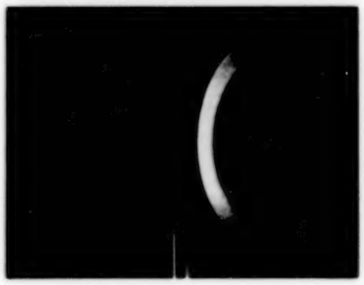
[*] COSMIC is a registered trademark of the National Aeronautics and Space Administration.

Publications

An essential measure in promoting greater use of NASA technology is letting potential users know what NASA-developed technologies are available for transfer. This is accomplished primarily through the publication *NASA Tech Briefs*.

The National Aeronautics and Space Act requires that NASA contractors furnish written reports containing technical information about inventions, improvements and innovations developed in the course of work for NASA. These reports provide the input for *Tech Briefs*. Issued monthly, the free publication is a current awareness medium and a problem solving tool for more than 200,000 government and industry readers. It is a joint publishing venture of NASA and Associated Business Publications of New York City.



Each issue contains information on newly developed products and processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs, and other innovations originating at NASA field centers or at the facilities of NASA contractors. Firms interested in a particular innovation can get more detailed information by requesting a Technical Support Package (TSP); more than 135,000 such requests are filled annually.

An example of how *Tech Briefs* inspires secondary applications of NASA technology is the experience of the Laser Applications Laboratory of Air Products and Chemicals, Inc., Allentown, Pennsylvania. Working with high energy excimer lasers, the laboratory had a safety problem in that the ultraviolet light within the wavelength range of excimer lasers is invisible and can cause damage to eyes and tissue. It was necessary to develop an apparatus to contain or block the ultraviolet beam so that researchers could move around in the target areas without shutting off the laser.

An essential component of such an apparatus is a beam block for effectively trapping laser light — but there were no commercially available beam stops suitable. Air Products decided to develop its own.

While planning an approach, company scientists read in *NASA Tech Briefs* of related work on ultraviolet light absorption performed by Jet Propulsion Laboratory (JPL). They requested and received a TSP describing in detail the JPL invention, which involves use of a graphite plate mounted to an aluminum heat sink for absorbing light from high energy lasers.

Air Products incorporated the technology into its beam stop. The main element of the company's development is an aluminum cylinder (***left***), its inner surface roughened by machining turns to maximize light reflection and capture. The NASA technology is a plate bolted onto an aluminum heat sink and attached to the rear of the cylinder. ***Below***, an Air Products physicist is aligning the beam stop so that it interrupts the laser pathway and absorbs the beam. ●

NASA'S TECHNOLOGY TRANSFER NETWORK

The NASA system of technology transfer personnel and facilities extends from coast to coast. For specific information concerning the activities described below, contact the appropriate technology transfer personnel at the addresses listed, or address inquiries to the Manager, Technology Transfer Office, Center for AeroSpace Information, 800 Elkridge Landing Road, Linthicum Heights, Maryland 21090.

▲ ***Field Center Technology Utilization Officers:*** manage center participation in regional technology transfer activities.

▼ ***National Technology Transfer Center:*** national information, referral and commercialization service for NASA and other government laboratories.

■ ***Regional Technology Transfer Centers:*** information, technical and commercialization services.

● ***The Computer Software Management and Information Center (COSMIC):*** offers government-developed computer programs adaptable to secondary use.

★ ***Application Teams:*** assist agencies and private institutions in applying aerospace technology to solution of public problems.

▲ Field Centers

Ames Research Center
National Aeronautics and
Space Administration
Moffett Field, California 94035
Technology Utilization Officer:
Geoffrey S. Lee
Phone: (415) 604-4044

Goddard Space Flight Center
National Aeronautics and
Space Administration
Greenbelt, Maryland 20771
Technology Utilization Officer:
George Alcorn, Ph.D.
Phone: (301) 286-5810

Lyndon B. Johnson Space Center
National Aeronautics and
Space Administration
Houston, Texas 77058
Technology Utilization Officer:
Richard B. Ramsell
Phone: (713) 483-3809

John F. Kennedy Space Center
National Aeronautics and
Space Administration
Kennedy Space Center, Florida
32899
Technology Utilization Officer:
James A. Aliberti
Phone: (407) 867-3017

Langley Research Center
National Aeronautics and
Space Administration
Hampton, Virginia 23665
Technology Utilization Officer:
Joseph J. Mathis, Jr.
Phone: (804) 864-2484

Lewis Research Center
National Aeronautics and
Space Administration
21000 Brookpark Road
Cleveland, Ohio 44135
Technology Utilization Officer:
Anthony F. Ratajczak
Phone: (216) 433-5568

George C. Marshall Space Flight Center
National Aeronautics and
Space Administration
Marshall Space Flight Center,
Alabama 35812
Director, Technology Utilization
Office:
Ismail Akbay
Phone: (205) 544-2223

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109
Technology Utilization Manager:
Wayne Schober
Phone: (818) 354-2240

NASA Resident Office—JPL
4800 Oak Grove Drive
Pasadena, California 91109
Technology Utilization Officer:
Arif Husain
Phone: (818) 354-4862

John C. Stennis Space Center
National Aeronautics and
Space Administration
Mississippi 39529
Technology Utilization Officer:
Richard A. Galle
Phone: (601) 688-1929

■ Regional Technology Transfer Centers

1-800-472-6785 You will be connected to the RTTC in your geographical region.

FAR WEST
Technology Transfer Center
University of Southern
California
3716 South Hope Street,
Suite 200
Los Angeles, California 90007
Robert Stark, director
Phone: (213) 743-6132
(800) 642-2872 (California only)
(800) 872-7477 (toll-free US)

NORTHEAST
Center for Technology Commercialization, Inc.
Massachusetts Technology Park
100 North Drive
Westborough, Massachusetts 01581
William Gasko, Ph.D., director
Phone: (508) 870-0042

MID-WEST
Great Lakes Industrial Technology Center
25000 Great Northern Corporate Center, Suite 260
Cleveland, Ohio 44070
Joseph W. Ray, Ph.D. director
Phone: (216) 734-0094

SOUTHEAST
Southern Technology Application Center
University of Florida
College of Engineering
Box 24
One Progress Boulevard
Alachua, Florida 32615
J. Ronald Thornton, director
Phone: (904) 462-3913
(800) 225-0308 (toll-free US)

MID-CONTINENT
Texas Engineering Experiment Station
Texas A&M University System
237 WERC
College Station, Texas 77843
Gary Sera, director
Phone: (409) 845-8762
(800) 548-1536 (toll-free US)

MID-ATLANTIC
University of Pittsburgh
823 William Pitt Union
Pittsburgh, Pennsylvania 15260
Lani Hummel, director
Phone: (412) 648-7000
(800) 257-2725 (toll-free US)

● Computer Software Management and Information Center

COSMIC
382 E. Broad Street
University of Georgia
Athens, Georgia 30602
John A. Gibson, director
Phone: (706) 542-3265

★ Technology Application Teams

Research Triangle Institute
Post Office Box 12194
Research Triangle Park, North Carolina 27709
Doris Rouse, Ph.D., director
Phone: (919) 541-6980

Technology Application Center
University of New Mexico
2500 Yale Boulevard S.E., Suite 100
Albuquerque, New Mexico 87131
Stan Morain, Ph.D., director
Phone: (505) 277-3622

▼ National Technology Transfer Center

Wheeling Jesuit College
Wheeling, West Virginia 26003
Lee W. Rivers, executive director
Phone: (304) 243-2520

NASA Center for AeroSpace Information

Technology Transfer Office
800 Elkridge Landing Road
Linthicum Heights, Maryland 21090
Walter Heiland, manager
Phone: (410) 859-5300, extension 241

Spinoff Team:
Project manager:
Walter Heiland

Senior Technology Associate:
Jane Lynn-Jones

Graphic Services:
The Watermark Design Office
Alexandria, Virginia

Photography:
Kevin Wilson
Silver Spring, Maryland

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